Assessment of the Impact of Removal of Alien Species and Succession in The Nilgiris

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Final Report

Study commissioned by

Forest Genetics Division
Tamilnadu Forest Department
Coimbatore

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Study carried out by

Care Earth Trust
Biodiversity. People. Conservation

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Project Context

Tamilnadu Forest Department through its Research Wing, commissioned Care Earth Trust for an assessment of the biodiversity after the removal of Invasive Alien Species through specific programmes in the Nilgiris, and to evolve recommendations for improved and long-term management of the issue, covering aspects such as recovery of habitats and monitoring processes and tools. The assessment was carried out in areas operated under the schemes *viz.*, HADP, Project Tiger, Environment Protection and Renewal Energy Development (EPRED), Fodder and Pilot scheme.

Three forest divisions in the Nilgiris were chosen as the project sites for the current assessment *viz.*, Nilgiris North and South forest divisions and Mudumalai Tiger Reserve. Records from the TN Forest Department were studied to obtain an understanding of the total area that was targeted for the removal of IAS. The field study was carried out between February 2016 and December 2017.

Invasive Species Removal Programme

One of the policy initiatives of Tamil Nadu Forest Department is to check the growth of Invasive Species and adverse impact on Forests:

The policy envisages

- To carry out site specific coordinated invasive species removal programmes.
- To control, remove the invasive species, and bring the affected areas invaded by weeds to near-natural forests status.

Hill Area Development Programme

A targeted removal of select IAS was carried out in the Nilgiris by the Tamil Nadu Forest Department (TNFD) with financial support from the Hill Area Development Programme (HADP) and Project Tiger. HADP is a Nilgiris specific programme being implemented by Government of Tamil Nadu, since inception of the Fifth Five Year Plan. The State Government has adopted eco-restoration, eco-preservation and eco-development, and the socio-economic and developmental needs of the district as the basic objectives of HADP in the Nilgiris.

Field study

Care Earth conducted intensive field surveys and collected data on present biodiversity and recruitment status in the operated areas. The field works were to observe the ground truth of the efficiency of the scheme that got implemented; which forms the base for the study. Primary and secondary data pertinent to invasive species removal has also been undertaken.

To assess the impact of removal of Invasive Alien Species in selected forest divisions of Nilgiris, both biotic and abiotic factors will be taken in to consideration. Primary investigations had been done before starting the field woks that included the criteria chosen for earmarking sites for removal and about the abutting landscape. Plots were established permanently to monitor the efficiency of removal. Number of plots and their size were decided based on the total area of operation in each forest division. In each plot, the following components were assessed.

Since Nilgiris boasts various types of forests, the problematic species in the landscape varies depending on the vegetation type. This study has been carried out in three different forest types, Deciduous, Evergreen and Scrub; Lantana, Wattle and Cactus are the target invasive species for removal respectively. The results are also arrived according to the above mentioned forest type.

A total of nine study plots and three control plots (for each vegetation type) measuring 100 x 100 m were established in seven forest ranges and three forest divisions. Each one Ha. plot is marked with Sub-plots of size 10x10 m in all the corners and in the middle. Totally, there are 45 subplots that were used for the assessment of recruitment of saplings, and indigenous plants. The altitude of the study locations ranged from 800 to 2280 m above mean sea level.

Biodiversity component

The main target of the current project is to assess the changes in biodiversity in the selected locales. Biodiversity to be assessed are plant communities and associated faunal groups. This is done in two stages of assessment, *viz.*, preliminary and quantitative.

- **Generic assessment-** Generic assessments provide an understanding of the geography of the landscape. As static living organisms, plants (trees, shrubs and lianas of Angiosperms) are easy to measure for their presence and absence, as also quantify its phenology.
- **Indigenous flora-** Native plants are the true representatives of natural forests. The performance of indigenous plants in the study area is an important indicator to know the efficiency of removal of invasives. The quantitative assessment of higher plants will help to understand the status of native flora. Further, the long-term monitoring will reveal whether there is a decline or increase in indigenous plant population. The outcome of this study will evince the efficacy of native plants in controlling the spread of invasive species.

- **Plant community succession-** Plants that colonise landscape vigorously and establish themselves faster that other plant communities are called Pioneers. Many of our indigenous plants are pioneers, which sometimes are misconstrued as Invasive species. These pioneer species vary across landscape, influenced largely by altitude and local conditions.

Faunal groups- Avifauna (birds) was studied systematically for its distribution and diversity in each sample plot. Considering the fact that bird taxonomy is well established, inventory will be prepared for both pre-monsoon and for post-monsoon seasons. The latter faunal groups have been recorded for their presence within plots, by the experts in field team. The overall faunal data for any given plot will be the list of animals that uses the landscape as resident and those make their passage through the operated area.

I. Introduction

The world has seen the introduction of many plant species for agriculture, horticulture, forestry, medicine, ornament, trade and scientific curiosity over the millenia. Countries like India which are historically known for trading in biological resources, such as spices and condiments have sizable share of introduction of exotic plants. These plants have provided us with countless economic and social benefits. An unexpected consequence of the introduction of thousands of plant species into cultivation was the extension of considerable numbers of them from agricultural fields and botanic gardens into disturbed habitats and some of these in turn became naturalized and a threat to natural plant communities (Heywood and Sharrock, 2013). This was not appreciated until recently and today such alien and invasive plants are seen as a major threat to biodiversity conservation besides having serious social, health and economic consequences. In fact, **the term 'Invasive Alien Species (IAS)[1] came into reckoning amongst a wider group of people and governments, largely after the Convention on Biological Diversity came into force in the year 1992.** The CBD also ensured that a definitive nomenclature was in place especially with reference to designation of species.

Biological Diversity is broadly defined as the variations and variability (conspicuous and cryptic) in form and function, of living organisms and the living systems that they sustain, across space and time (CBD, 1992). Following the Convention on Biological Diversity, a concerted global effort was launched to assess the consequences of ecosystem change for human well-being and to analyse options available to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being. Christened as the Millennium Ecosystem Assessment (MEA), the effort was conducted during 2001-2005 and involved 1360 experts from 95 countries. The MEA developed four global scenarios exploring plausible future changes in drivers, ecosystems, ecosystem services, and human well-being. It also examined the strengths and weaknesses of various response options that have been used to manage ecosystem services, and identified promising opportunities for enhancing human well-being while conserving ecosystems.

It follows that the loss of biodiversity and degradation of ecosystems inevitably affects human well-being, contributing to lower food security, harsher living conditions, worsening health, and reduced wealth. Particularly vulnerable are the poor, who, to a large extend, are directly dependent on biodiversity-based goods and the associated ecosystem services for their livelihoods. The Millennium Ecosystem Assessment identified the main drivers of biodiversity loss and ecosystem services as climate change, unsustainable resource use in the form of overexploitation, pollution and habitat destruction, and invasive alien species – all due to human activity. The assessment established the strong connotation that invasive alien species have on decreased availability of biodiversity for the poor and marginalized communities.

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[1] Although it has been suggested that the acronym IAS to denote Invasive Alien Species be changed to InAS while being used in India, in the absence of a formal recognition of this recommendation, the standard acronym of IAS is being retained in the current report.

The Debate on Invasive Species

The history of debate on Invasive Alien Species is rather interesting, with (Larson 2013; Heywood 2008, 2013), Invasive Alien Species often evoking strong emotional responses; sometimes reflected in the terms which are applied to them, such as 'Mongolian invaders', and approaches to limit or control introduced species being criticized as being nativist, racist or xenophobic (Simberloff 2003). At the same time, it has been postulated that some non-native species can provide conservation benefits and instead of just focusing on their negative effects, the potential benefits of the species may be considered in reaching a judgment. **Researchers have also called for a more meaningful definition of an invasive species - which would be a species for which there is a net negative effect (Schlaepfer et al., 2011).** The CBD sought to provide a more acceptable understanding and approach to the issue through the Aichi Targets, specifically *Target 9.*

Target 9

Convention on Biological Diversity defines biodiversity loss as "the long-term or permanent qualitative or quantitative reduction in components of biodiversity and their potential to provide goods and services, to be measured at global, regional and national levels". The Convention's member countries have committed to achieving a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth by 2010. The Target is articulated as follows:

"By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment."

The Definitions and Dynamics

Species is one of the basic units of biological classification and a taxonomic rank. A species is defined as a group of organisms capable of interbreeding and producing fertile offspring.

Indigenous species- Plants that are found native to specific habitat for a specified geological time scale are termed as indigenous; they occur naturally in the wild without any aid from anthropogenic activities. These plants are vital to maintain and sustain the local biodiversity; which in fact helps in the larger ecological succession. Physiologically, these species grow slowly and lack robust seed dispersal mechanism. Only the natural resources are utilized by these plants and so they are more resilient; unless for biological invasion. Isolation is one of the primary attributes essential to retain indigenous species.

Exotic, Non-native, Alien Species- These are species that are from other geographies or foreign in origin, introduced for ornamental, agriculture, or for other commercial and forestry purposes.

Naturalised species- These are non-native species that are found growing naturally in an ecosystem, without either proliferating or intruding into the habitats of other species. These can also be termed exotics that are not invasive. Many species such as *Tridax procumbens* are seen commonly in many vegetation types, but are easily out-competed by the indigenous species. Most plant species that have an agriculture/horticulture connotation are found in this category. It is also to be noted that in rare instances, a naturalized species might become invasive after many years of existence in the landscape.

Pioneer species- Pioneer species are those plants that emerge and colonise in cleared or open spaces faster than other native plants. These are hardy species and will utilize the nutrients from soil quickly after any kind of fire, moving or complete grazing. By colonizing in the disrupted ecosystem, these plants form the first ecological succession in a landscape, thus forming the basis of a steady-state bio-diverse ecosystem. The physiological adaptations of such species include longer roots, fast-growing meristems and vigorous vegetative growth apart from demanding sunlight. The density of these plants normally reduces once secondary succession starts, the pioneers become a part of the system by being represented by limited number of individuals. Some of the Lichens are also considered as pioneers, apart from higher plants.

A point of caution that many well-meaning groups/organisations and individuals fail to recognize is that certain indigenous plant species act as pioneers in a natural environment, and misconstrued as 'invasives'. The sudden sprouting and vegetative establishment as pure stands will make them appear as though they are an invasive community. Many of the pioneers are non-invasive, and short-lived in comparison to other plant communities in the successional stages.

Invasive / Invading / Invasive Alien Species

An invading species is defined as the one showing the establishment of self-sustaining plant populations that are expanding within a natural plant community with which they had not previously been associated (Vitousek et al. 1995). An exotic plant enters an ecosystem, when there is a chink in niche of the species and then become invasive. The break in ecological niche is caused by anthropogenic interference disturbing the species package. Any intact ecosystem is likely to be non-susceptible for the intrusion by exotic species.

Plants that are labelled as 'weeds' are native to otheir place of origin. The labelling is because of their non-use character to humans, and by no means a description of their invasiveness. It is hence important to appreciate that the two terms 'exotic weeds' and 'Invasive Alien Species' are not synonyms.

Plant invasions occur when species are transported to, and establish in new and often distant ranges (Elton, 1958; Mack et al., 2000). **Invasive Alien Species (hereinafter referred as IAS) are described as a 'catastrophic wildfire in slow motion' as they cross geographic boundaries, spanning landscapes, and depict their potential to annihilate the ecosystem. IAS are the second imminent threat to biodiversity after habitat loss apart from intimidating food security**. A recent analysis of IUCN Red List data highlighted invasive alien species as the fifth most severe threat to amphibians, and the third most severe threat to birds and mammals. Together with climate change, they have become one of the most difficult threats to reverse.

Pure Stands- Unlike mono-culture which is a man-made plantation, some invasive plants form pure stands that will not allow any other ecological succession to ensue. Many factors are attributed for the exotics to evolve in to this stage. Pure Stands of invasives are the extreme maturity of bio-invasion in an area, which will obliterate the indigenous species not sparring the saplings. 'Heavy growth' is the term used in local forestry for defining this deleterious condition in forests. These patches form high density of seed bank in the soil.

Factors favouring invasiveness

A multitude of factors that govern the invasiability of species have been studied, some of which are highlighted in the following section.

Invasiveness is the characteristic associated with species that proliferates in new habitats; whereas, Invasiability is an attribute which defines the susceptibility of habitats to the establishment or proliferation of non-native species. Introduction of an exotic plant may be intentional or unintentional (accidental). Plantations, ornamental gardening, farming, etc., are the main ways of intentional introduction to the ecosystem. Unintentional plant introductions mostly occur by imports and travelling; classic example being the coconuts dispersed in seas and natural disasters.

Established and abundant bio-invaders generally occupy similar habitats as native species. Abundant species tend to be less affected by competitors; and in a study that spanned many locations, germination success and reproductive output were significantly positively associated with invasiveness when results from both stages (establishment/ spread and abundance/impact) were combined (Colautti, 2006). Interestingly, research on invasions has been of interest since the time of Charles Darwin (1859) who was the first scientist to study specific factors relating to invasions.

The mechanisms of bio-invasion could be broadly divided into species-based and ecosystem-based. A study found that from a list of invasive and non-invasive species, 86% of the invasive species could be identified from the traits alone. Disturbance regimes, zero-sum resource systems and propagule pressure are the factors in the ecosystem (or habitat) that helps in rendering to the non-natives the character of 'invasiability'. Disturbance regimes are mostly through forest fires, fragmentation of habitats, soil erosion, etc., that contribute to the opening up of the canopy, or creating edge effects.

The lesser visible, thereby lesser known traits of a species that favour invasiveness include,

- Facilitation by allelopathy (interference competition)
- Rapid growth and reproduction
- Phenotypic plasticity
- Anthropocentric associations
- Habitat generalist
- Establishing multi-traits

Invasibility of plant communities

Plant communities change with time due to changes in the environment, biotic interactions and invasions of alien species and genotypes, introduced intentionally or accidentally by humans. It is only recently that bio-invasions are receiving serious attention. Indeed, there have always been a migration of taxa, but now the rate of human-assisted introductions of new taxa is several orders of magnitude higher. Of special interest is the relationship between invasive and local native species and the often different behaviour of invasive species in their new, alien environment. An interesting suggestion is that invasibility (ability to invade) of plant a community is mainly caused by fluctuations in resource availability (cf. Grime 2001).

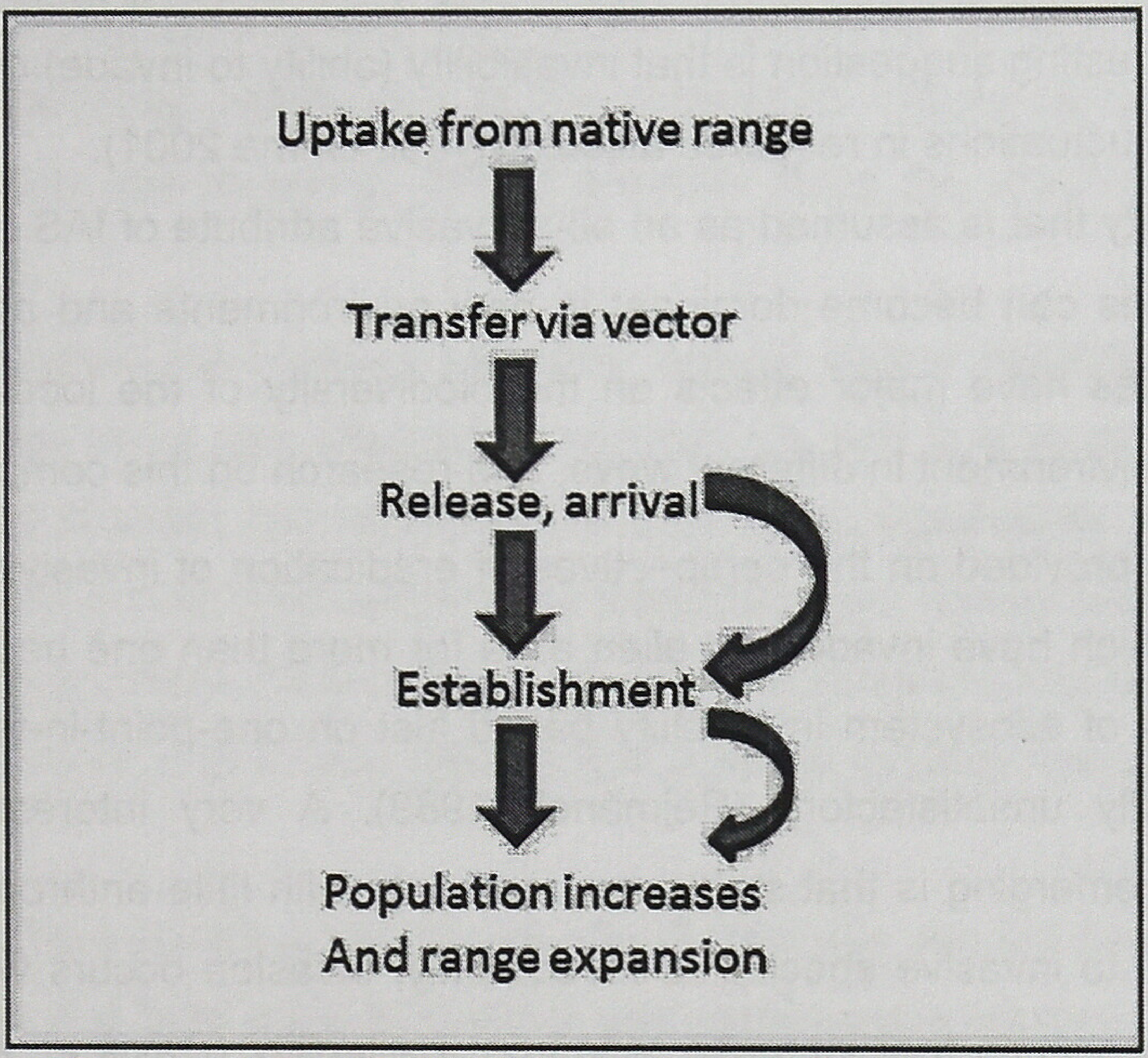
Yet another complexity that is assumed as an all-pervasive attribute of IAS is the following: only a few invasive species can become dominant in new environments and act as a 'transformer species'. Such species have major effects on the biodiversity of the local native community. They transform the environment in different ways, and research on this complexity is minimal.

Useful information is provided on the perspectives of eradication of invasive species. As a rule of thumb, species which have invaded an alien area for more than one hectare, can hardly be eradicated. Analyses of ecosystem invasibility based just on one-point-in-time observations (*a posteriori*) are usually unsatisfactory (Rejmánek 1989). A very interesting and important supposition which is emerging is that stable environments with little anthropogenic disturbance tend to be less open to invasive species. Consequently, invasion occurs when niche vacancy exists following disturbances that increase resource availability (Davis et al. 2000, Davis and Pelsor 2001), or when competitors and natural enemies suppress indigenous species' performance (Keane and Crawley 2002, Zuppinger-Dingley 2011). The ability to exploit available resources depends on functional differences among species, which are considered proportional to invasive ability (Naeem et al. 2000, van Kleunen et al. 2010).

Propagule pressure

The minimum amount of seed or individuals of a plant required for establishing a colony in a foreign (non-native) landscape is called propagule size. Propagule pressure is termed as 'introduction effort', a combination of measures to release individuals into a region to which they are not native (Carlton, 1996). After initial establishment, the propagules expand their geographical range. Increasing propagule size enhances establishment probability primarily by lessening effects of demographic stochasticity, whereas propagule number acts primarily by diminishing impacts of environmental stochasticity (Simberloff, 2009). ***Propagule pressure is one of the important factor by which the invasive alien species thrives on.***

Propagule pressure includes variation in the composition, quantity, and rate of supply of non-native species resulting from the transport conditions and pathways between source and recipient regions (Richardson, 2011). Therefore, measures of propagule pressure generally involve (i) the number of individuals introduced ('propagule abundance'), (ii) the number of taxa or genotypes introduced ('propagule richness') and (iii) the total number or frequency of introduction events.



Edge effects

The changes in ecological paramaters and plant communities in the edges of an ecosystem are termed as Edge effects. This is one such severe effect when a canopy of an intact forest opens. ***Invasive alien species find their way easy to establish in the 'ecotones', the transitional boundary between two different habitat types. The open lit canopy helps the invading plants to proliferate in shorter time period for producing the necessary propagules*** (seed bank). ***Habitat fragmentation also favours the edge effect, thereby inviting the potential non-native species to become invasive.*** It is generally recognized that fragmenting the contiguous forest into smaller patches diminishes both the quantity and quality of the remaining forest interior habitat; loss of interior habitat in late successional or old-growth forests is of particular concern especially in Mudumalai Tiger Reserve.

Edges are either "inherent" or "induced" (Thomas et. al.1979). An inherent edge is a natural, usually long-lasting, feature of the landscape, which may be related to: topographic differences, soil type, the presence of open water-body, geomorphic or landform factors. Induced edges are caused by both natural and anthropogenic disturbances, like fire, flood, erosion, deforestation, heavy grazing. When these edges are abrupt, exotic species will find a niche here owing to the micro-climatic regime. Edge effects can have serious impacts on species diversity and composition, community dynamics, and ecosystem functioning (Laurance, 1991).

- Invasive alien species have since the 17th century contributed to nearly 40% of all animal extinctions for which the cause is known.
- Annual environmental losses caused by introduced pests in India, United States, United Kingdom, Australia, South Africa and Brazil have been calculated at over US$ 100 billion
- Invasive alien species can transform the structure and species composition of ecosystems by dominating the ecosystems and repressing or excluding native species
- Because invasive species are often one of a whole suite of factors affecting particular sites or ecosystems, it is not always easy to determine the proportion of their impact (www.cbd.int/invasives).

Impacts of alien invasive species on forests

1. Ecological and environmental- The full economic costs of invasions include not only the direct damage and control costs but also the effects on the ecosystems themselves. The ecological and environmental impacts of alien invasive species can be felt by all levels of organization including the gene, species, habitat and ecosystem level.

- **Genes**-If introduced or spread into habitats with closely related species, alien invasive species could interbreed with native species resulting in changes to the genetic makeup of either species. The possible negative consequences of such alterations include reduction in the survival of both the species, creation of a more successful invader, or the creation of hybrids that could be more susceptible to certain pests and pathogens.
- **Species**- Alien invasive species can influence species diversity, richness, composition and abundance. At the species level, direct effects of alien invasive species occur through processes such as the predation of, competition with, and pathogen and parasite transmission to individual organisms, eventually leading to population declines and species extinctions.
- Through direct impacts on species or through alterations of habitats, alien invasive species are responsible for placing 762 forest species at risk (IUCN, 2005). The loss of

such species is leading to a more homogenous world which is perhaps the biggest threat to global biological diversity, behind habitat loss.

- **Habitats-** Through their impacts on species and ecosystem processes, alien invasive species can result in the fragmentation, destruction, alteration or complete replacement of habitats which in turn, has cascading effects on even more species and ecosystem processes.
- **Ecosystems-** The impacts of alien invasive species at the ecosystem level include changes to trophic structures, changes in the availability of resources such as water and nutrients, and changes in the disturbance regimes. • Invasive alien plants and trees have decreased water supplies for nearby communities and increased fire hazards in South Africa (McNeely et al., 2001; van Wilgen et al., 2001; Petit et al., 2004).
- Invasive grasses that are particularly fire-prone may lead to a permanent loss of forests (Mooney and Hofgaard, 1999).

2. Social and health impacts

The full costs of invasions also include the social and health impacts of alien invasive species on humans, in particular to the rural communities depending on forests. As a result of the negative impacts of alien invasive species on native forest biodiversity, a loss of food sources and traditional medicines may be experienced thereby compromising not only the health of local people, but also the livelihoods of those dependent on the collection and sale of such items for income. For small-scale landowners, alien invasive species can also decrease the value of their land.

Forest workers, as part of their jobs, and people living in and around invaded forest areas may also suffer allergic or other negative reactions to the alien invasive species themselves or to the measures used to control them such as chemical and biological pesticides. A commonly planted tree for land restoration and as a source of forest products, Mesquite (*Prosopis juliflora*) is a major cause of allergies in India, Kuwait, Mexico, Saudi Arabia, South Africa, the United Arab Emirates and the southwestern United States. Sensitivity to Mesquite and Carrotgrass (*Parthenium*) pollens have been shown to result in asthma, rhinitis and conjunctivitis (Killian and McMichael, 2004).

(Source: http://www.fao.org/docrep/008/j6854e/J6854E06.htm).

The Nilgiris: a synoptic account

The global significance of the Nilgiri Hills was recognized rather early in the history of biodiversity studies in India. As a result, the Government of India, in compliance with the UNESCO's Man and Biosphere Programme, declared the Nilgiri Hills that span the states of Tamil Nadu, Kerala and Karnataka as the country's first Biosphere Reserve in the year 1986. The Nilgiri Biosphere Reserve (NBR) that covers an area of over 5,500 sq.km is known for its remarkable biodiversity and high levels of endemism that about a decade later it appeared as India's first Biosphere Reserve in the UNESCO's world map of biosphere reserves (Daniels, 1993).

It is now well established that the Western Ghats that cradles NBR is a biodiversity hotspot, wherein the rich and highly endemic diversity of species, communities and habitats are faced with imminent threats of degradation and extinction. In this regard, NBR may be called a 'hotspot' within the hotspot in that the very character of one of earth's oldest hill ranges and the associated endemic biodiversity is far more precariously sustained.

Amongst others, unplanned development and the associated human pressures have posed a major challenge to the long-term management of NBR (Daniels and Vencatesan, 2008). Chief among the associated human pressures is the widespread invasion of the natural habitats of NBR by alien plants. While there are hundreds of non-native herbs, grasses and shrubs that have run wild since the Europeans first colonized the hills, extensive plantations of trees like the wattle and pine have destroyed habitats pushing out with them many of the indigenous species of plants and animals.

In Tamil Nadu, two major ecosystems are affected by invasive alien species. The forest ecosystem of Western Ghats has been severely affected by the naturalized/invasive alien species (IAS). Hill towns such as Ooty and Coonoor in the Nilgiri hills and Kodaikanal in the Palani hills were colonized by the British who introduced a number of Mediterranean and European plants which helped to mimic the landscape of Europe. Few plants were introduced along with the establishment of the tea estates. *Erigeron karvinskianus* (Fleabane Daisy) for example, is introduced as a plant to strengthen the walls of the estates. Srivastava & Singh (2009) have provided consolidated and updated information on major forest invasive species of flowering plants India. The Nilgiris and Dindigul districts harbour majority of the alien/invasive species (Table 11) according to the ENVIS database on flowering plants of Tamil Nadu (http://tnenvis.nic.in) (Narasimhan et al. 2010).

II. Objectives

Tamilnadu Forest Department commissioned Care Earth Trust for an assessment of the species diversity and distribution after the removal of Invasive Alien Species through specific programmes in the Nilgiris, and to evolve recommendations for improved and long-term management of the issue, covering aspects such as recovery of habitats and monitoring processes and tools. The field study was carried out between February 2016 and December 2017.

The specific objectives of the project included:

1. To conduct a baseline survey of biodiversity in critical habitats where Invasive Alien Species have been removed.
2. To assess conservation status of species found in the areas after removal of alien species.
3. To identify the spots where species richness is high across all floral and faunal groups.
4. To identify resource-rich areas and possible spots of endemicity.
5. To create GIS based maps through extensive surveys, which help in management of both natural resource and biodiversity.
6. To assess the recruitment and replacement of indigenous species in the operated area.

III. Methodology and Tools

The following methodology and tools were used to carry the present study.

1. Study of project background

Care Earth conducted intensive field surveys and collected data on invasive plants removal. This includes the name and year of the scheme under which the removal works happened. The field works were to observe the ground truth of the efficiency of the scheme that got implemented; which forms the base for the study.

- Study of secondary sources of data, notably project reports
- Interviews with the project implementing agency; review of the results

2. Impact Assessment

To assess the impact of removal of Invasive Alien Species in selected forest divisions of Nilgiris, both biotic and abiotic factors will be taken in to consideration. Primary investigations had been done before starting the field woks that included the criteria chosen for earmarking sites for removal and about the abutting landscape. Plots were established permanently to monitor the efficiency of removal. Number of plots and their size were decided based on the total area of operation in each forest division. In each plot, the following components were assessed.

Biotic Changes (Biodiversity component)

The main target of the current project is to assess the changes in biodiversity in the selected locales. Biodiversity to be assessed are plant communities and associated faunal groups. This is done in two stages of assessment, viz., preliminary and quantitative.

Changes in biodiversity that can be attributed to the removal of IAS were assessed by studying plant communities and associated faunal groups. While it is desirable to study all the major faunal groups, due to constraints of time and resources, it was decided to limit the focus to major vertebrate and butterflies. The assessment had two components viz. generic and quantitative.

- **Generic assessment-** Generic assessments provide an understanding of the geography of the landscape. As static living organisms, plants (trees, shrubs and lianas of Angiosperms) are easy to measure for their presence and absence, as also quantify its phenology.
- **Indigenous flora-** Native plants are the true representatives of natural forests. The performance of indigenous plants in the study area is an important indicator to know the efficiency of removal of invasives. The quantitative assessment of higher plants will help to understand the status of native flora. Further, the long-term monitoring will reveal whether there is a decline or increase in indigenous plant population. The outcome of this study will evince the efficacy of native plants in controlling the spread of invasive species.
- **Plant community succession-** Plants that colonise landscape vigorously and establish themselves faster that other plant communities are called Pioneers. Many of our indigenous plants are pioneers, which sometimes are misconstrued as Invasive species. These pioneer species vary across landscape, influenced largely by altitude and local conditions. Given this, every plot established was observed to record the dynamics of the pioneer species focusing on the peak season of spread.

Faunal groups- All-out-search method has been carried out for studying the associated animal species in the landscape. Avifauna (birds) was studied systematically for its distribution and diversity in each sample plot. Considering the fact that bird taxonomy is well established, inventory will be prepared for both pre-monsoon and for post-monsoon seasons. The latter faunal groups have been recorded for their presence within plots, by the experts in field team. The overall faunal data for any given plot will be the list of animals that uses the landscape as resident and those make their passage through the operated area.

3. Field Assessment

All the plots were sampled in four different seasons to obtain robust data on change in species. Summer, post-southwest monsoon (SWM), northeast monsoon (NEM) and post-northeast monsoon are the seasons chosen for sampling, since Nilgiris district receive substantial rainfall during the southwest monsoon period.

Field research using standard methods such as Nested plots, All-out-search and inventorying. As stated in the earlier sections of the report, the study comprised of a review of secondary literature, key informant discussions and field surveys. Field surveys were preceded by a reconnaissance study to identify patches / plots where removal of IAS had been undertaken during various years under different schemes. The results are as follows:

Various researches have estimated that over 1599 species belonging to 842 genera in 141 families of vascular plants (roughly 8.5 percent of total Indian flora) are categorized as alien and invasive species and a large portion of it being potentially invasive in our country (Kuroo et.al., 2012). Bearing the tag of World Heritage site, forests of Nilgiris are believed to be choked by the Invasive Alien species and in the absence of long term studies on the invasive alien flora spread over the natural forest and grasslands, robust protocols for removal or management are still in the process of being evolved. Paucity of long term data on the nature, spread, intensity and impact of the IAS on the landscape is probably the single most important factor impacting the management of IAS, especially of plants.

Hence, criteria used to identify patches for removal of IAS were largely based on aspects such as-

- Visual assessment by the frontline staff
- Efficient removal and safe disposal
- It is also to be recognized that the landscape harbors a significant population of large mammals, which needs to be factored into the criteria for selecting patches for removal of IAS.

Based on the area of removal, sites were earmarked for the assessment. The number and size of plots were decided based on the total extent of removed (operated) area in that particular forest division. Each plot measured 100 X 100 m, with locale specific variation. Within each of the plots, plants with straight boles from ground up to or more than 1.5 metres are considered as trees. The girth (GBH) was measured at breast height (c. 1.34 m); also, trees with GBH above 10 cm alone were recorded. Trees with less than 10 cm girth were recorded under shrubs. Height of the shrubs was noted and this applies to saplings too. Herbaceous flora was recorded as inventory at every field visit; helping to analyse presence or absence data. Reproductive phenology for all the plants was recorded systematically in the field. Field assessments were carried out to cover the three predominant seasons of the region viz. summer, pre-monsoon and post monsoon.

The plots

A total of nine study plots and three control plots (for each vegetation type) measuring 100 x 100 m were established in seven forest ranges and three forest divisions. Each one Ha. plot is marked with Sub-plots of size 10x10 m in all the corners and in the middle. Totally, there are 45 subplots that were used for the assessment of recruitment of saplings, and indigenous plants. The altitude of the study locations ranged from 800 to 2280 m above mean sea level. A schematic plan of the plots is depicted in the following diagram, followed by a GIS image of the plot locations, while Table 1 & 12 lists the geo-coordinates of the sample plots that were established.

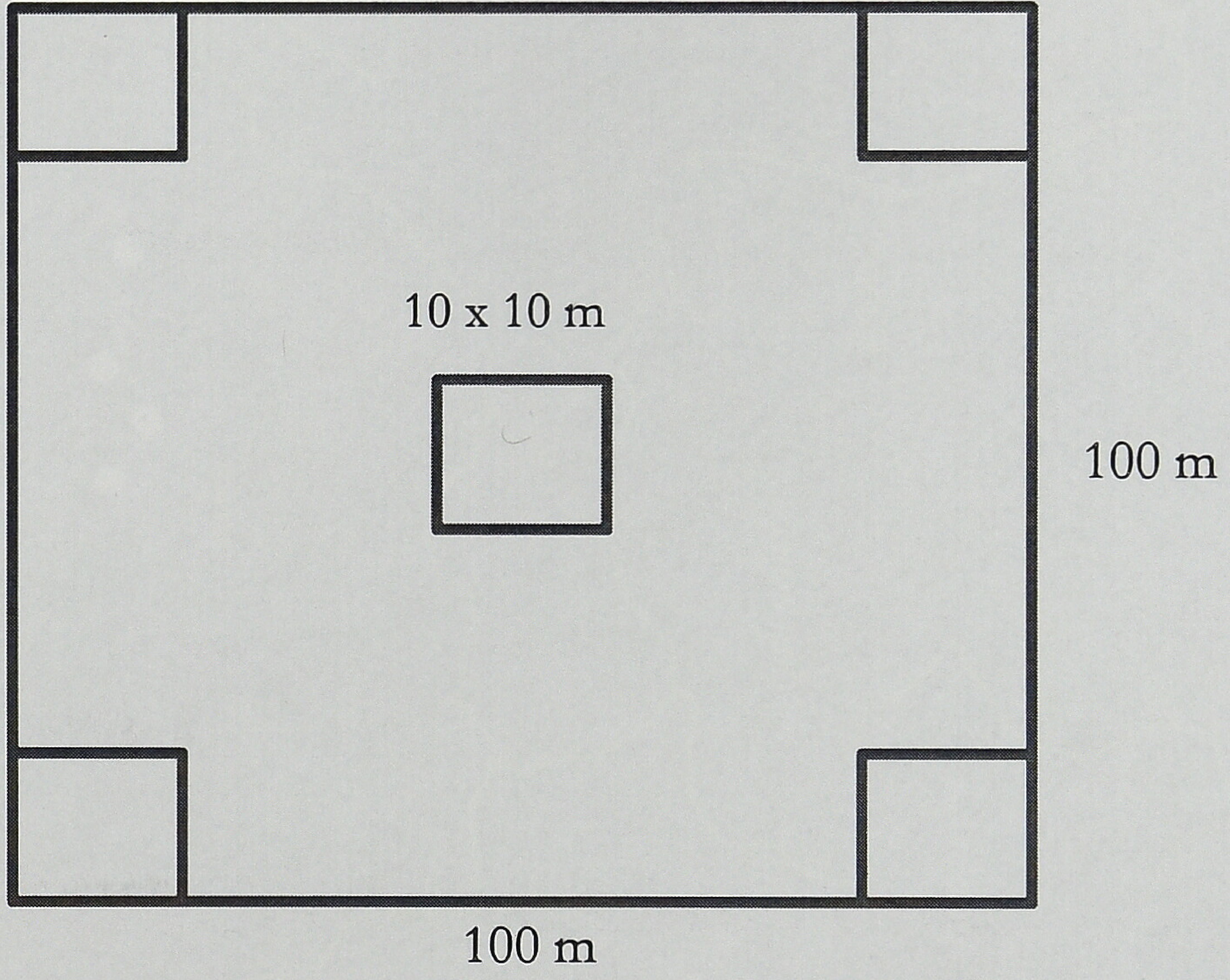


Figure 1: Schematic representation of the sample plots layout

Table 1: Location of the plots

Forest Range	Reserve Forest	Location	Latitude (N)	Longitude (E)	Altitude (m)
Masinagudi	Moyar	Periyakulam	11.57734	76.57895	895
Masinagudi	Moyar	Maanboard	11.57878	76.60401	913
Teppakadu	Kumbarakolli	Camp	11.58257	76.58694	873
Kargudi	Kumbarakolli	Kallhalla	11.58198	76.56889	912
Singara	Segur North	Mayilarapatti	11.539463	76.746417	904
Segur	Segur North	Mayilarapatti	11.539098	76.743053	906
Pykara	Wenlock Downs	Kulimund	11.490791	76.612885	2126
Pykara	Wenlock Downs	Glenmorgan	11.481561	76.61112	2060
Naduvattam	Carriot Shola	Carriot Shola	11.428132	76.536714	2248
Control					
Teppakadu	Kumbarakolli	Teppakadu	11.609563	76.57372	956
Naduvattam	Nigiri Peak	Mudimund	11.40951	76.53091	2288
Segur	Segur North	Jagglikadavu	11.573465	76.707637	871

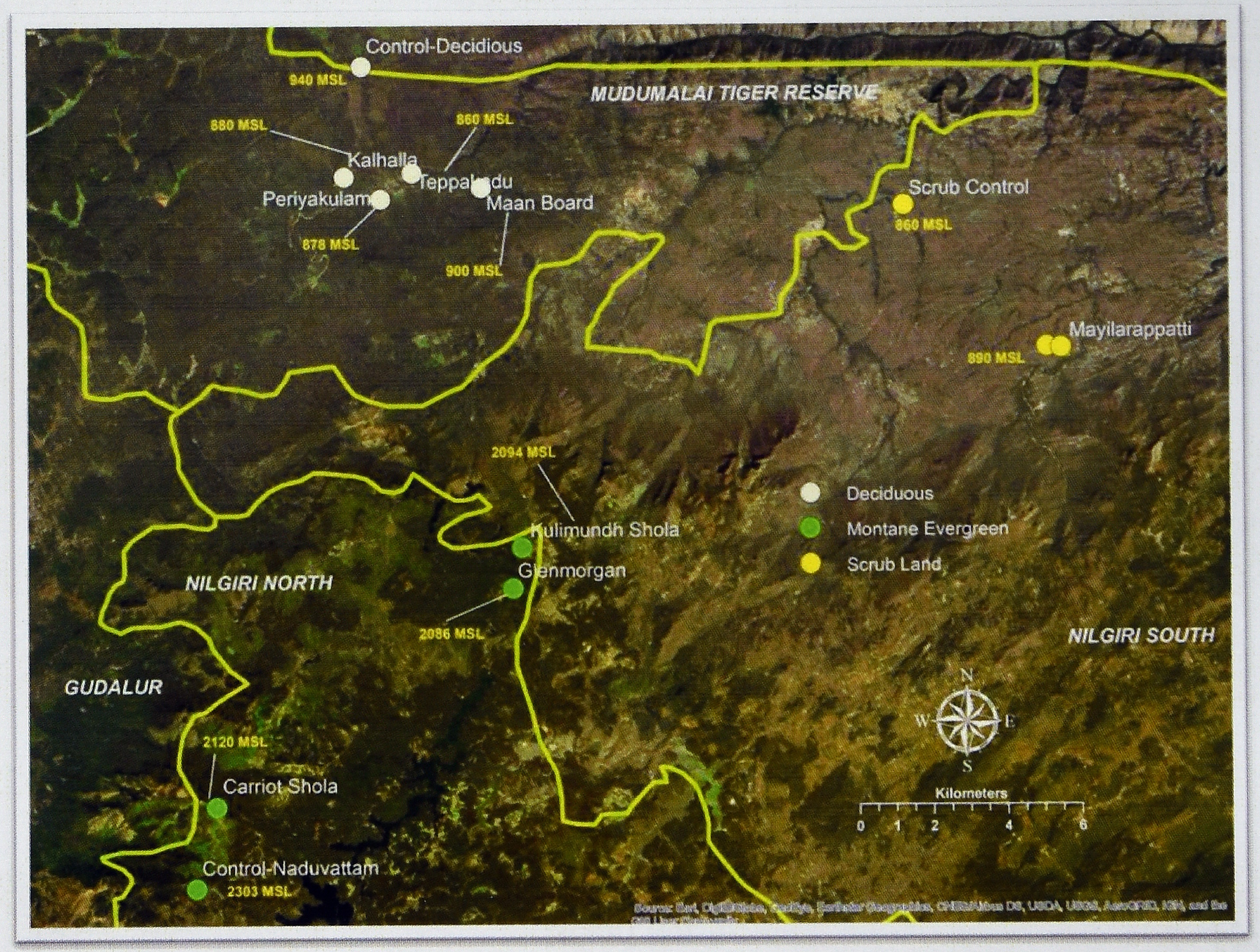

Control-Decidious
940 MSL
MUDUMALAI TIGER RESERVE
880 MSL
860 MSL
Kalhalla
Teppakadu
Periyakulam
Maan Board
878 MSL
900 MSL
Scrub Control
860 MSL
Mayilarappatti
890 MSL
2094 MSL
Kulimundh Shola
Glenmorgan
2086 MSL
NILGIRI NORTH
Deciduous
Montane Evergreen
Scrub Land
NILGIRI SOUTH
GUDALUR
N
W
E
S
Kilometers
0
1
2
4
6
2120 MSL
Carriot Shola
Control-Naduvattam
2303 MSL

Figure 2: Map showing the plot locations

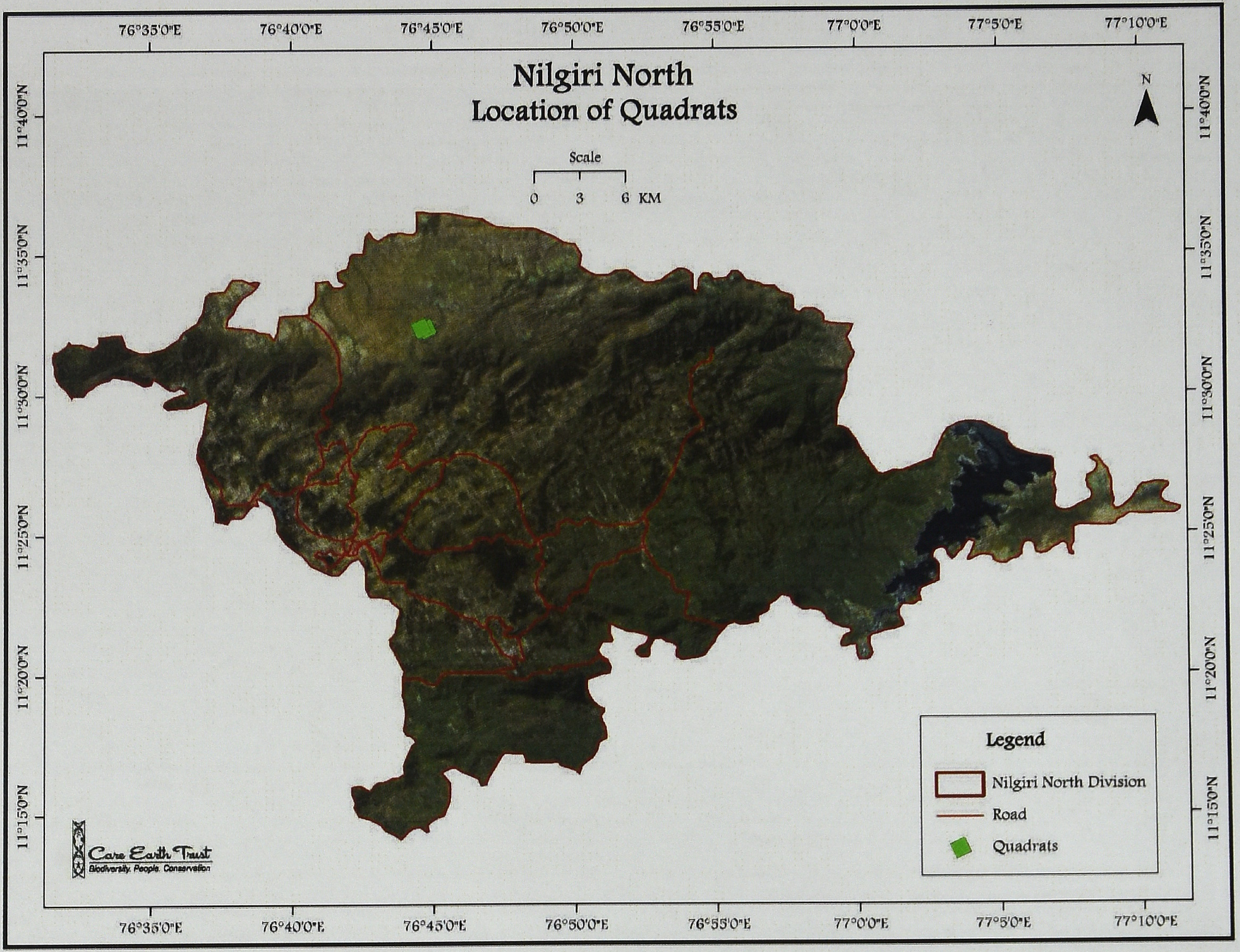

76°35'0"E
76°40'0"E
76°45'0"E
76°50'0"E
76°55'0"E
77°0'0"E
77°5'0"E
77°10'0"E
11°40'0"N
11°35'0"N
11°30'0"N
11°25'0"N
11°20'0"N
11°15'0"N
Nilgiri North
Location of Quadrats
Scale
0 3 6 KM
N
Legend
Nilgiri North Division
Road
Quadrats
Care Earth Trust
Biodiversity. People. Conservation

Figure 3: Location of quadrats in Nilgiris North division

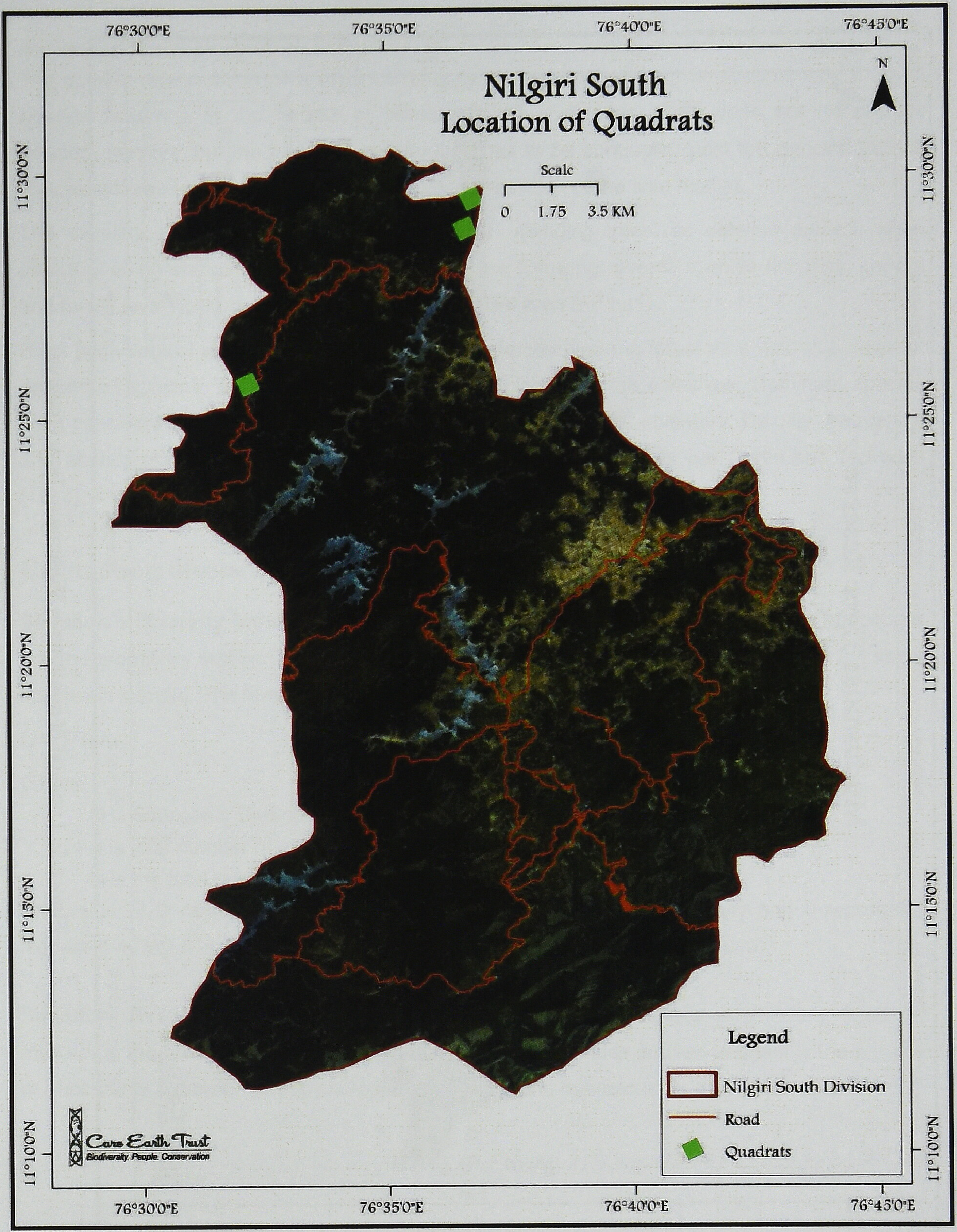

Nilgiri South
Location of Quadrats
Scale
0 1.75 3.5 KM
N
76°30'0"E
76°35'0"E
76°40'0"E
76°45'0"E
11°30'0"N
11°25'0"N
11°20'0"N
11°15'0"N
11°10'0"N
Legend
Nilgiri South Division
Road
Quadrats
Care Earth Trust
Biodiversity. People. Conservation

Figure 4: Location of quadrats in Nilgiris South division

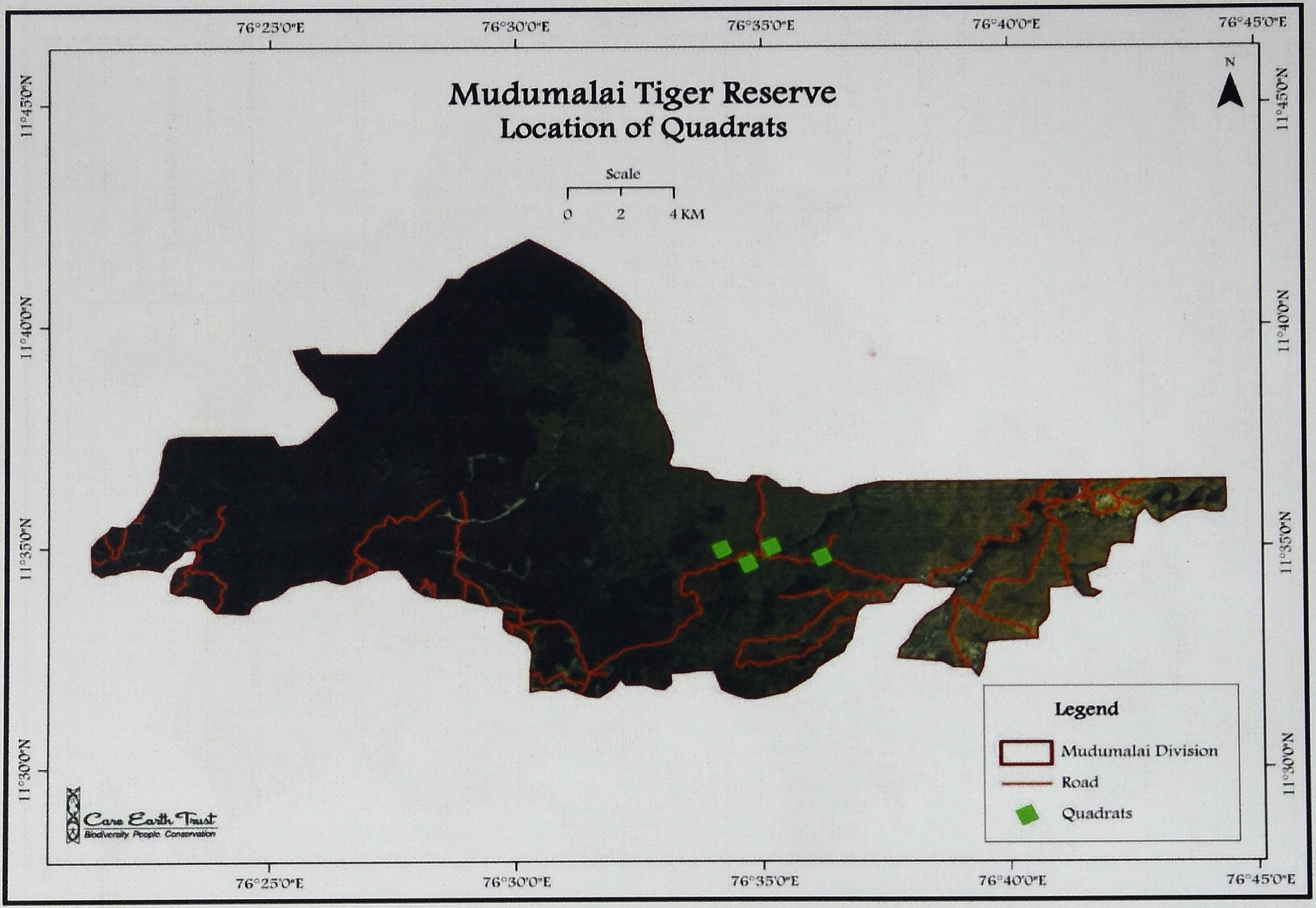

Mudumalai Tiger Reserve
Location of Quadrats
Scale
0
2
4 KM
N
76°25'0"E
76°30'0"E
76°35'0"E
76°40'0"E
76°45'0"E
11°45'0"N
11°40'0"N
11°35'0"N
11°30'0"N
Legend
Mudumalai Division
Road
Quadrats
Care Earth Trust
Biodiversity. People. Conservation

Figure 5: Location of quadrats in Mudumalai Tiger Reserve

4. Species and their dynamics

The species composition of a plant community, in its simplest form is discerned by a list of species occurring in the habitat or landscape. An evaluation study does not necessitate replicate surveys, but the baseline enumeration has to be conducted post the removal of IAS. This would result in defining the plant species composition of the said habitat.

The baseline enumeration and measurements of standing trees (as detailed earlier), when analysed using standard indices would provide the following: overall species richness, genera and family level richness, species diversity and basal area ($m^2\ ha^{-1}$).

Plant phenological studies are fundamental for understanding the forest as a resource base for dependent species, populations and communities, including the invasives. Dominant species were considered to be those that were the most abundant in the inventory. Density, frequency, and abundance of woody angiosperm species were determined as per Curtis and McIntosh (1950).

Calculating diversity

Simpson's Diversity Index (D) is calculated for measuring the relative abundance of species. It is the probability that two individuals randomly selected from a sample will belong to the same species in sample. The formula for calculating D index is as follows,

$$D = \sum (n/N)^2$$

Where,

D is Simpson's Diversity Index

n is total number of a particular species

N is the total number of all the species in a plot

The value of **D** ranges between 0 and 1. Here, 1 represents no diversity and 0 represents highest diversity. The formula was developed by Edward Hugh Simpson (1949).

Shannon diversity index is also called as Shannon-Weiner index is a widely used for measuring the diversity of species in a given sample. This index is used to quantify the entropy or uncertainty. Shannon entropy is represented by **H** and expressed as a positive value.

$$H = -\sum_{i=1}^{s} (P_i * \ln P_i)$$

Whereas,

H = Shannon diversity index
P_i = fraction of the entire population made up of species i
S = numbers of species encountered
$\sum$ = sum from species 1 to species S

Natural logarithm (ln) has been used here. A community with only one species would have an H value of 0 because P_i would equal 1 and be multiplied by ln P_i which would equal zero. If the species are evenly distributed, then the H value would be high. So, the H value allows us to know not only the number of species but how the abundance of the species is distributed among all the species in the community. This index for calculating species diversity was developed by Claude Elwood Shannon and Norbert Weiner in 1963.

Species evenness is measured using Pielou's measure of species evenness (Pielou, EC., 1966) and represented by **J'**. The value suggests the closeness of species package in a community (quadrat). J' is constrained between 0 and 1. The less variation in communities between the species, the higher J' is.

$$\mathbf{J = H' / \ln(S)}$$

Where, **H'** is Shannon diversity index and **S** is the total number of species in a sample, across all samples in dataset.

Importance Value Index

Importance Value Index (IVI) is calculated for each species found in the study area to estimate which species is dominating and can be commonly seen in the location (Table 15-17). The index is universally used for assessing the site occupancy and importance of species in forestry and vegetation ecology. The percentage values of the relative frequency, relative density and relative dominance are summed up together to obtain the IVI of the species (Curtis, 1959).

Basal Area: a woody species' basal area is measured with the help of a standard measuring tape. The girth (circumference) at breast height (GBH) is measured at approximately 1.3 metres of the tree trunk from ground level. It is used to measure of cross-sectional area of a tree trunk. If diameter is expressed in units of meters (m), then the area calculation will have units of m^2. A hectare is defined as 100 m X 100 m or 10,000 m^2. It is recorded as follows

$$\mathbf{(DBH)^2 * (\pi/4)}$$

This can be expanded as: $\mathbf{BA\ (m^2) = pi * DBH^2_{(cm)} / 40000}$

The following formula is used to convert the GBH in to diameter: **DBH = GBH / π**

Total Basal Area is calculated by the summation of all the values of a particular species found in all the plots. Trees present per hectare represents the stand density.

Relative Species Density

Relative density is the expression of the relative numerical strength of a species where the total number of individuals of each species in all the quadrats is divided by the total number of quadrats studied; and represented in percentage. It is the numerical strength of a species in relation to the total number of individuals of all the species.

$$\text{Relative Density} = \frac{\text{Density of a particular species x 100}}{\text{Total density of all species}}$$

Relative Frequency

This term refers to the relative degree of dispersion of individual species in an area and usually expressed in terms of percentage occurrence. It was calculated by sampling the study area at several places and by recording the occurrence of the species in each sampling unit. It is calculated by the equation:

$$\text{Relative Frequency} = \frac{\text{Number of quadrats in which the species occurred X 100}}{\text{Total number of quadrats (frequency) studied}}$$

Relative Dominance

Dominance of a species is determined by the value of the basal cover. Relative dominance is the coverage value of a species with respect to the sum of coverage of the rest of the species in the area. The percent Total Basal Area of a species in all the plots refers to the dominance.

$$\text{Relative dominance} = \frac{\text{Total basal area of the species X 100}}{\text{Total basal area of all the species}}$$

IV. Results and Discussion

The removal of invasive species by the Forest Department in Nilgiris has been carried out largely under two projects/programmes.

i. Hill Area Development Programme

A targeted removal of select IAS was carried out in the Nilgiris by the Tamil Nadu Forest Department (TNFD) with financial support from the Hill Area Development Programme (HADP) and Project Tiger. HADP is a Nilgiris specific programme being implemented by Government of Tamil Nadu, since inception of the Fifth Five Year Plan. The State Government has adopted eco-restoration, eco-preservation and eco-development, and the socio-economic and developmental needs of the district as the basic objectives of HADP in the Nilgiris.

As mandated, three forest divisions in the Nilgiris were chosen as the project sites for the current evaluation viz., Nilgiris North and South forest divisions and Mudumalai Tiger Reserve. Records from the TN Forest Department were studied to obtain an understanding of the total area that was targeted for the removal of IAS. Table 2 summarises the locations and the total area of operation.

ii. Tamil Nadu Biodiversity Conservation and Greening Project (TBGP)

Controlling and managing invasive species under TBGP envisaged survey, monitoring and reporting of invasive species and its removal in four Protected Areas and 10 Forest Divisions. Though Department estimated the area of occupation of invasive species in the State as around one lakh ha, GoTN contemplated trial removal of three invasive species viz., *Lantana, Prosopis* and Wattle in an area of 3,000 ha.

The component included uprooting the invasive species, turning the soil and immediate replanting with grasses and shrubs as appropriate. It was also envisaged for conduct of the baseline survey of the critical areas prior to removal and preparation of strategy and management manual during 2012-13 followed by the removal of species during 2013-14 to 2015-16. It was emphasised that the implementation of the component would be effective if the species were removed to contiguous areas without exception and were removed from the forest area. Further, regeneration of invasive species expected after a few years of removal, activities in the areas should be continued for the succeeding two to four years. The Governing Body of

TBGP resolved (May 2014) that the removal of invasive species had to be executed in one of the identified Range of each Divisional Management Unit (DMU).

The invasive species of Lantana, Prosopis and Wattle were removed in 2,684 ha from 2013-14 to 2016-17 by incurring the expenditure of 5.51 crore. Removal of *Lantana* was done in isolated patches of 1.5 to 10 ha in different Forest Ranges and partially in Nilgiris North DMU during 2015-16. In two DMUs- Nilgiris (North) and Nilgiris (South), invasive species of 6,869 cum of cut wattle wood and 59.95 MT of wattle bark though removed under the project were stacked inside the forest area resulting in non-adherence to the norms and possibility of regeneration of invasive species.

In the absence of sanction for removal of *Prosopis* in the identified areas of the field study, partial removal of the trees of invasive species in a location and non-selection of the entire area occupied by the invasive species in the same year indicated inadequate conservation of biodiversity activities.

(Source:
https://cag.gov.in/sites/default/files/audit_report_files/Chapter_2_Performance_Audit_of_Report_No_7_of_2017_-_Economic_Sector_Government_of_Tamil_Nadu.pdf)

Table 2: Details of clearance of invasive plants in Nilgiris

Year of operation	Scheme	Location	Total clearance (Ha.)
2013 – 2014	HADP	Pavermund	6
2013 – 2014	HADP	Carriot Shola	15
2013 – 2014	EPRED	Kulimund	9
2012 – 2013	HADP	Maanboard	22
2012 – 2013	HADP	Periyakulam	22
2014 – 2015	Project Tiger	Teppakadu	25
2013 – 2014	HADP	Mayilarapatti	100
2013 – 2014	HADP	Aanaikaal	90
2014 – 2015	Project Tiger	Kargudi	10

Likewise, data was sought and obtained from the TN Forest Department regarding the expenditure incurred for the removal of the IAS in the locations described in the previous table. The following table, and Annexure II provide details of the same.

Table 3: Expenditure incurred for the removal process in selected forest ranges

Forest Range	Total Area (Ha.)	Approximate area infested (%)	Amount Spent in INR / Ha.	Target Species	Labour wage INR /day
Pykara	3260	75	12,500	Wattle	300 / cu.m
Naduvattam	4020	60	12,500	Wattle	300 / cu.m
Segur	4196	60	6,000	*Lantana*	225
Singara	5100	60	6,000	*Chromolaena*	225
Masinagudi	8062	60	16,500	*Lantana*	320.25
Teppakadu	6330	65	16,500	*Lantana*	320.25
Kargudi	5468	50	16,500	*Chromolaena*	320.25

The Post Removal Scenario

The study sites have been classified based on the habitat types and species composition. Deciduous, Scrub and Montane are the three major habitat types within which the plots are located.

Control Plots- Areas where there is no operation of removal of invasive plants are chosen for studying and comparing as Control plots. The plots are also of same size and subplots have been laid for the detailed assessment of all plant forms. These plots are chosen not too far from the operated areas or the study plots. One control plot for each of the forest type was laid, that is under pressure from invasive plants at various degrees. However, the magnitude of IAS impact in the Controls are not exactly the same as that of the areas cleared; given the variable factors such as slope, aspect etc. The operated areas are only 1-3 years old, whereas, the reference plots that are infested, were not completely overrun by invasive plants. The density of invading plant population varies highly within a landscape, and hence it is quite difficult to choose an equivalent control plot for reference. The removal treatment was not uniform across the plots to compare with any reference plots.

1. Montane Temperate Forests

Nilgiris district is typified by the feature of possessing the highest number of plant species as well as the highest number of exotic species. The high elevation forests and grasslands in Nilgiris have been subjected to various land-use changes. Rainfall averages 2000 mm annually in Naduvattam to 1000 mm at Glenmorgon (Pykara). The plant species found here are evergreen and are classified under Sub Group 1A - Southern Tropical Wet Evergreen Forests as per Champion and Seth (1968). The wet evergreen forest is also known as 'Shola' locally, which is interspersed with grasslands. Grasslands are found in areas of high wind velocity that unfavours natural tree growth. Historically, these highlands were experimented with commercial plantation crops like Wattle, Eucalypts, Pine, etc.

In few places like Mukruthi, wattle plantations failed during the colonial period itself. But in many places, both the Shola and Grassland habitats are invaded by Wattle and scores of other invasive plants.

About the unique Shola forests

Champion and Seth (1968) classified Shola forests as Southern Tropical Montane Wet Temperate forest [subgroup 11A, type C1]. The origin of Shola thickets was studied by Blasco (1970) and Vishnu-Mitre (1971), and their ages were estimated using radiocarbon dating (in Nilgiris upper plateau). Sholas receive substantial rainfall from both the monsoons and being evergreen, support a wide array of life-forms. The canopy is very thick and appears in 'cauliflower' shape; tender leaves show red-brown hues of colour variation. The boles and stems are curved to give older appearance to individual trees.

Ecotones are zones where two different communities overlap each other or merge with each with their edges. The diversity of species is richer here. Many pioneer species and invasive find their way in the ecotones. Ecotone species in Shola are mostly temperate and frost resistant (Ranganathan, 1938; Blasco, 1970).

Removal process

The target species is a tree called Wattle (***Acacia mearnsii*** De Wild.) which has high tannin content in its bark. Being a legume plant, the tree produces loads of viable seeds through its pods. The symbiosis established with animals like Bonnet Macaque is through edible pods, young leaves and twigs. Removing this invading plant was done through girdling technique in few places, although this could be applied only to mature trees. Wattle produces robust seed bank as well as vigorous seedling and shows faster recruitment rate. Like Eucalypts and Pines, *Acacia melanoxylon* (Blackwood wattle) was found to be dominant in the landscape despite being younger to the indigenous *Syzygium* spp. (Table 15). Blackwood is dominant in terms of biomass and basal area; yet, the younger recruits of the same are relatively lesser sparse in dispersal. The control plot in Naduvattam records natural mortality of Wattle in its habitat and hence the grass (ground cover) started increasing after the monsoon.

Table 4: Girth-class interval in montane forest

GBH (cm)	No. of individuals
0 - 50	2
51 -100	9
101 - 150	6
151 - 200	2

Mechanical logging of the selected wattle species was carried out using tools. Care was taken not to remove the non-target species and also avoiding damage to the habitat, especially when the soil layer is delicate. The logged trees were made into coupes near the operated area; after which they were sold on auction by the local forest department. The bark was separated from the trunk and auctioned separately. A major difficulty in extracting this wood was due to the rugged terrain, slippery land and extreme weather conditions.

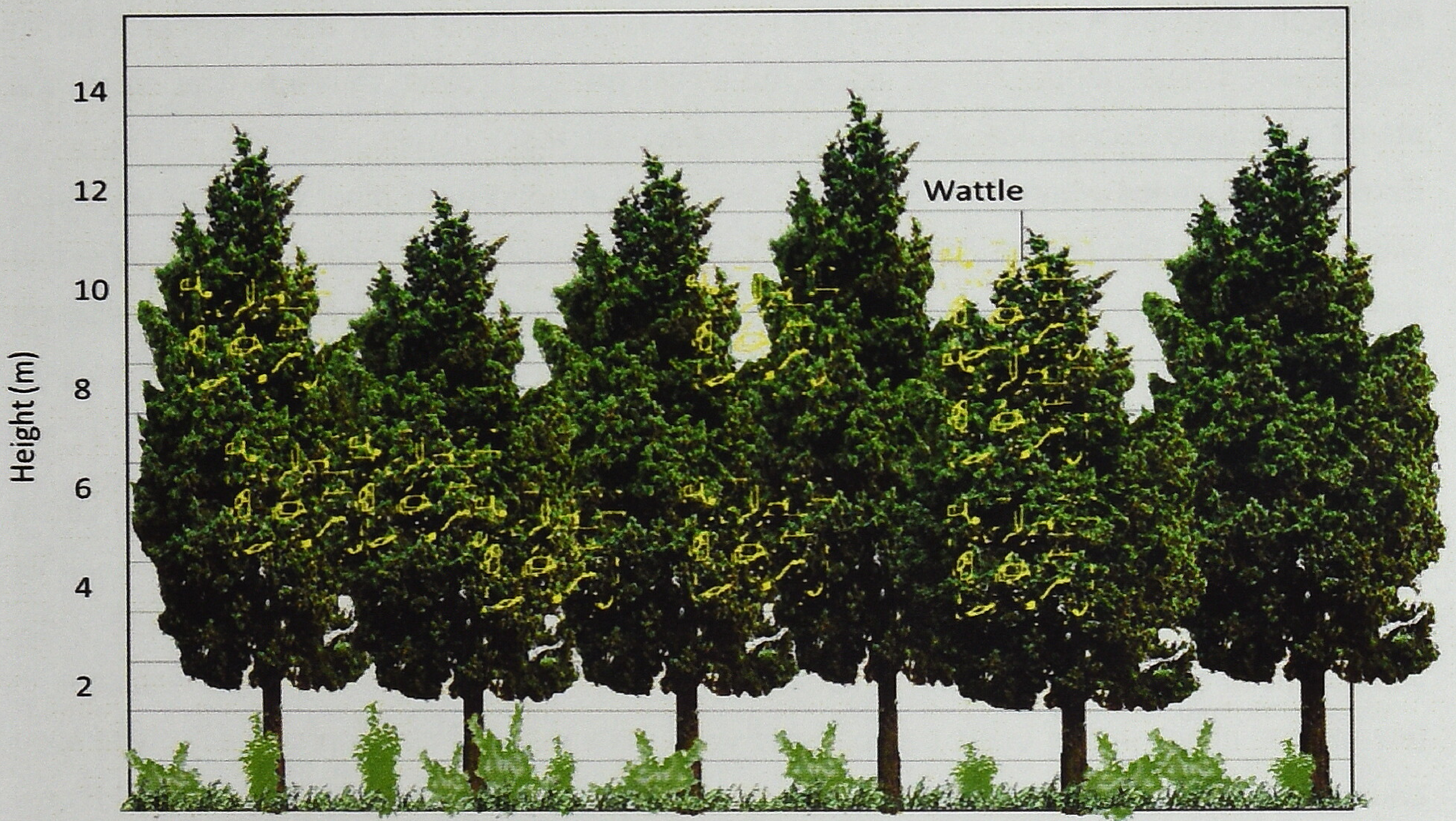


Figure 6: A schematic representation of the montane forest (Pykara) affected with IAS

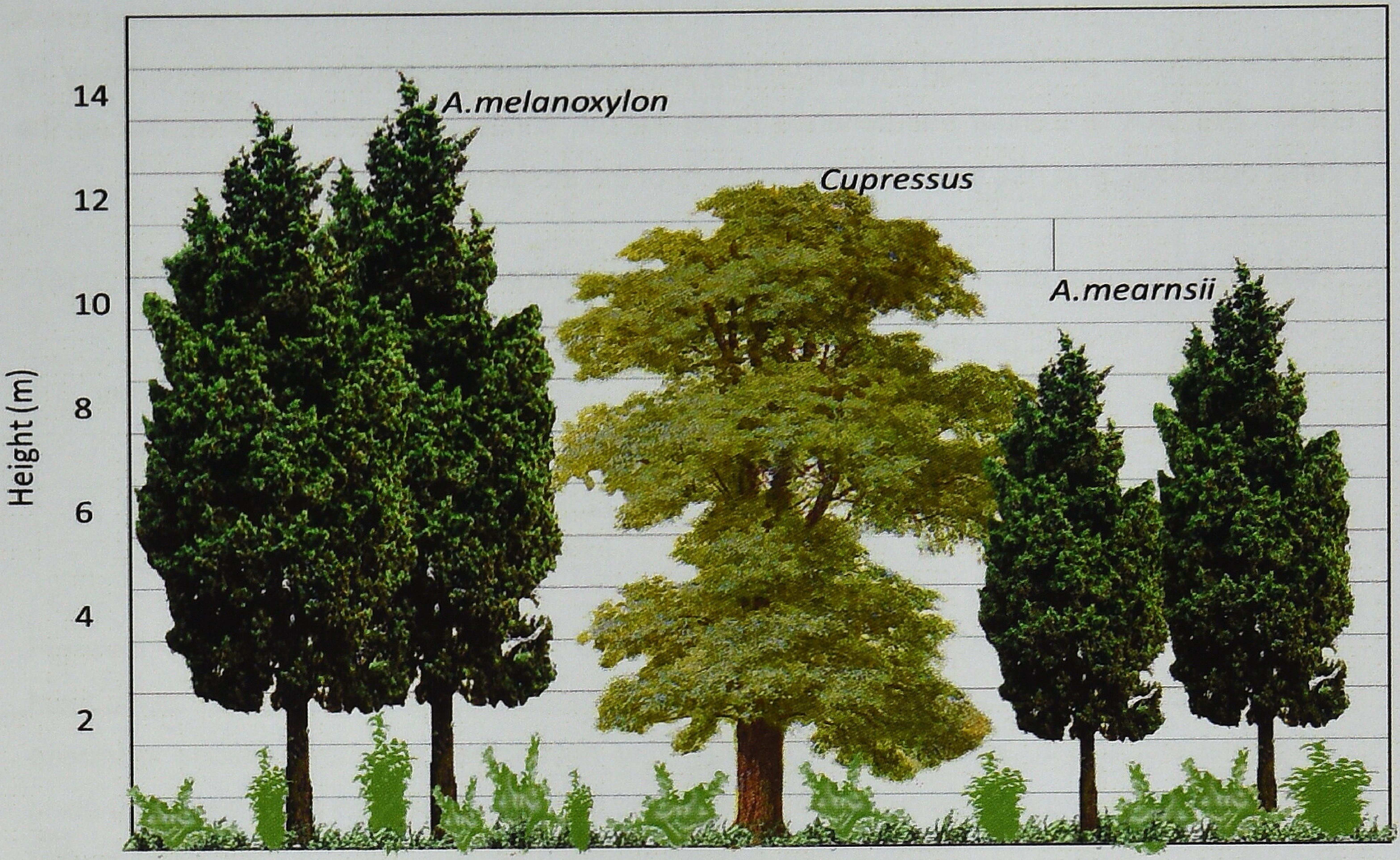


Figure 7: A schematic representation of the montane forest (Naduvattam) affected with Wattle

Efficiency of removal

Areas for operation were selected based on the intensity of infestation; they were linear as well as rectangular plots. Locations where the invading plants intruded into the natural forest system were also chosen to revive the montane shola forests (Pavermund RF of Glemorgan); part of the effort by TNFD in reestablishing indigenous vegetation. It was recorded that the removal process disturbed the top soil layer, thereby exposing the dormant seed bank of the wattle; ensuing shooting up of seedlings in a robust manner. It has been observed from the field, that the rate of spread of this invading species has not been reduced.

The invasive species in these highlands does not confine to Wattle alone, other plant invaders that usurp the nutrients from soil have been recorded (Table 9); but they are not included in the operation plan for removal. The congeneric invasive plants also favour the other exotics to suppress the recruitment rate of indigenous plant species. Being shade tolerant species, wattle, easily invades the impacted Shola forests from the edge, and establishes itself wherever there are small openings of the canopy. They outcompete the slow-growing indigenous trees to emerge in to upper canopy and suppress the former's growth. Selecting such disturbing exotic trees for removal proved efficient in reviving the local plant community. In some operated areas like Glenmorgan, plantation of indigenous species has been carried out for the recovery by TNFD. The lack of annual maintenance funds for the consecutive years has weakened the overall operation, and has impacted the recovery of the indigenous plant species.

Table 5: Operation details in selected patches for wattle tree removal (Year: 2013-2014)

Location	Area originally affected (%)	Area operated (Ha.)	Amount spent / Ha. (INR)	Maintenance	
				1st year	2nd year
Kulimund	75	9	12,500	No	No
Pavermund	75	6	12,500	Yes	Yes
Carriot Shola	70	15	12,500	Yes	Yes

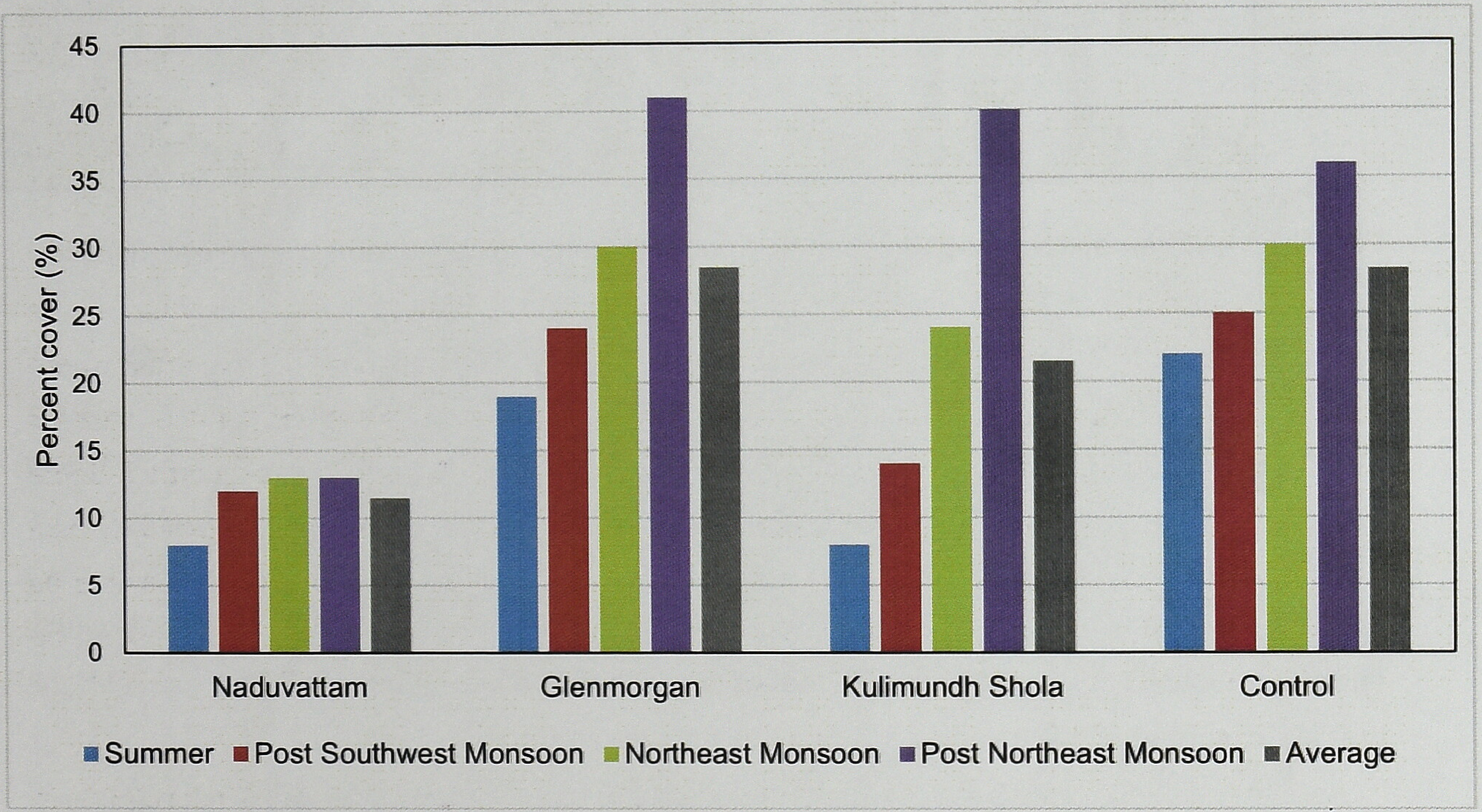


Figure: 8. Percent cover of IAS in montane forest plots

Amongst the plots, where wattle has been removed in montane temperate habitat, Naduvattam showed least invasive species cover a removal, followed by Kulimundh Shola and Glenmorgan.

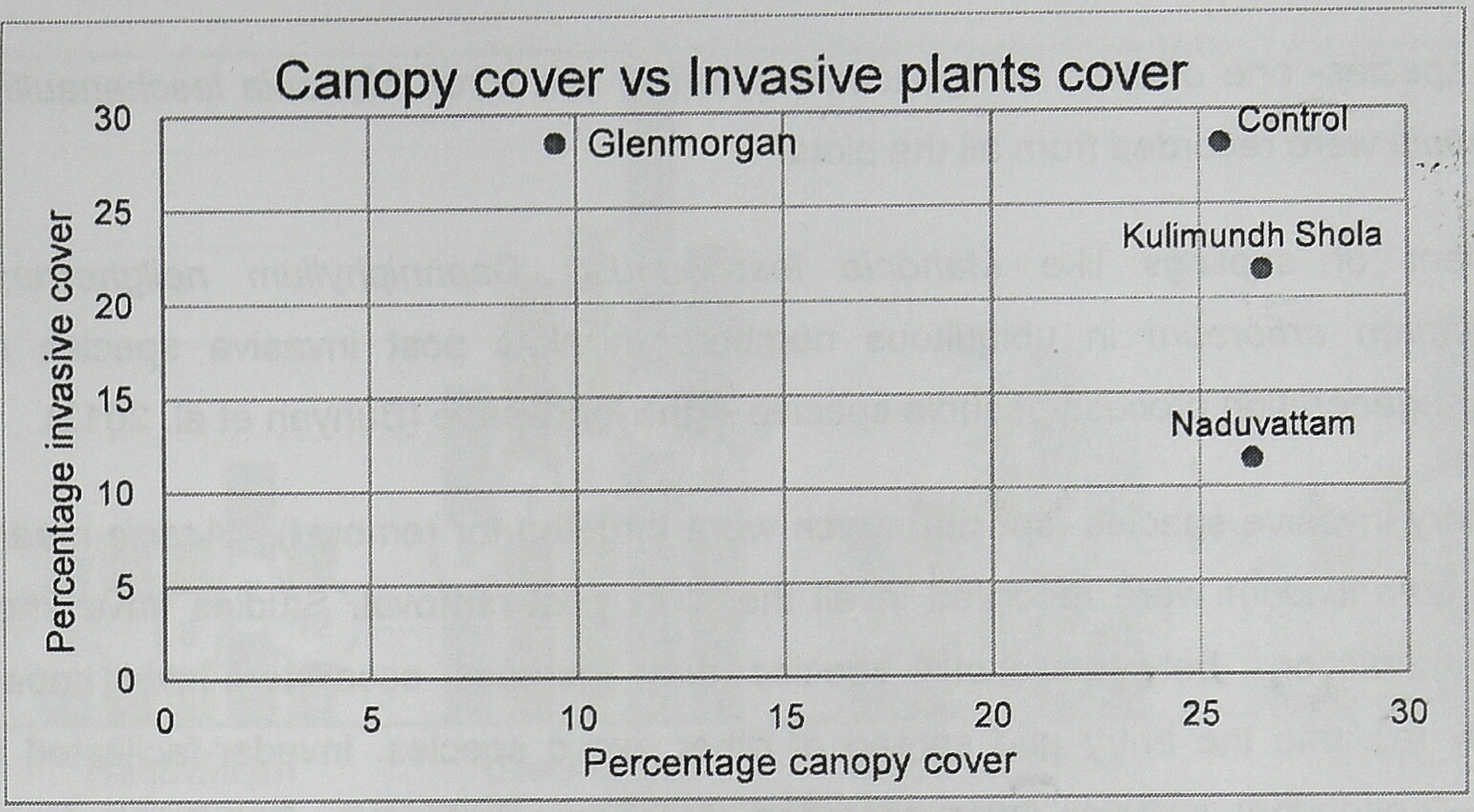


Figure 9: Relationship between canopy cover and invasive cover in montane habitat

Most alien plant species are open-habitat species. Therefore, at the site scale, canopy openness should favour the germination and growth of alien species, and at the landscape scale the presence of open habitat should increase the seed rain and therefore the colonization rate of forest sites by alien species (Charbonneau & Fahrig, 2004). To analyze the impact of canopy cover on re-invasion of the sample plots, canopy cover was plotted againt invasive species cover. It was found that in the case of plots in Naduvattam, where canopy cover was recorded to be high, the invasive species cover was low; in comparison to Glenmorgan where canopy cover was low and invasive species spread was high. However, in the case of Kulimundh Shola, despite having good canopy cover, high invasive spread was recorded. Some studies show that non-native species capable of invading undisturbed habitats, specifically high elevations and closed canopy forests may be particularly destructive to mountain systems as they are not dependent on disturbance for spread. Early identification of such species will be critical for successful control in mountain environments (Averett et al. 2016).

Analysing the recruitment of new species across seasons, highest number of saplings were recorded during post NEM in all the sample plots where invasive species has been removed as well as in control plots. Amongst the sample plots, highest recruitment was recorded in Glenmorgan followed by Kulimundh Shola and least in Naduvattam. However, overall, the saplings belonged to just two species in Glenmorgan (Pavermund). The number of newly recruited species was highest in Naduvattam (12), followed by 5 in Kulimundh Shola. This shows that though high number of saplings got established in Glenmorgan, they belonged to just two species- one of them being *Acacia mearnsii* and other *Mahonia leschenaultii*. Wattle and *Mahonia* were recorded from all the plots.

Recruitment of saplings like *Mahonia leschenaultii, Daphniphyllum neilgherrense* and *Rhododendron arboreum* in ubiquitous numbers in plots post invasive species removal, indicates regeneration process of shola species in the landscape (Bunyan et al. 2012).

The primary invasive species (species which were targeted for removal) - *Acacia mearnsii* and *Cestrum aurantiacum* were recorded in all the plots post removal. Studies have shown that positive interactions between exotic species may increase ecosystem-level impacts and potentially facilitate the entry and spread of other exotic species. Invader-facilitated invasion success—"secondary invasion" was recorded in the present case. Secondary invasion by *Ageratina adenophora* and *Solanum mauritianum* was recorded in all the plots during the monsoon seasons.

Overall, highest species richness was recorded during the post NEM assessment in all the plots including control, while the lowest richness was recorded during summer. Amongst the plots, where invasive species have been removed, highest species richness was recorded in Naduvattam, followed by Glenmorgan and Kulimundh Shola. Naduvattam also recorded the highest richness of indigenous species, followed by Glenmorgan and Kulimundh Shola.

A study by Unkule (2017) also revealed that there were not much change in the species richness across different sites, whether the wattle is cleared, or intact. This suggests that the wattle patches support most grassland species, but do not give it a conducive environment to spread. Once wattle is removed, grassland species spread and occupy the cleared areas.

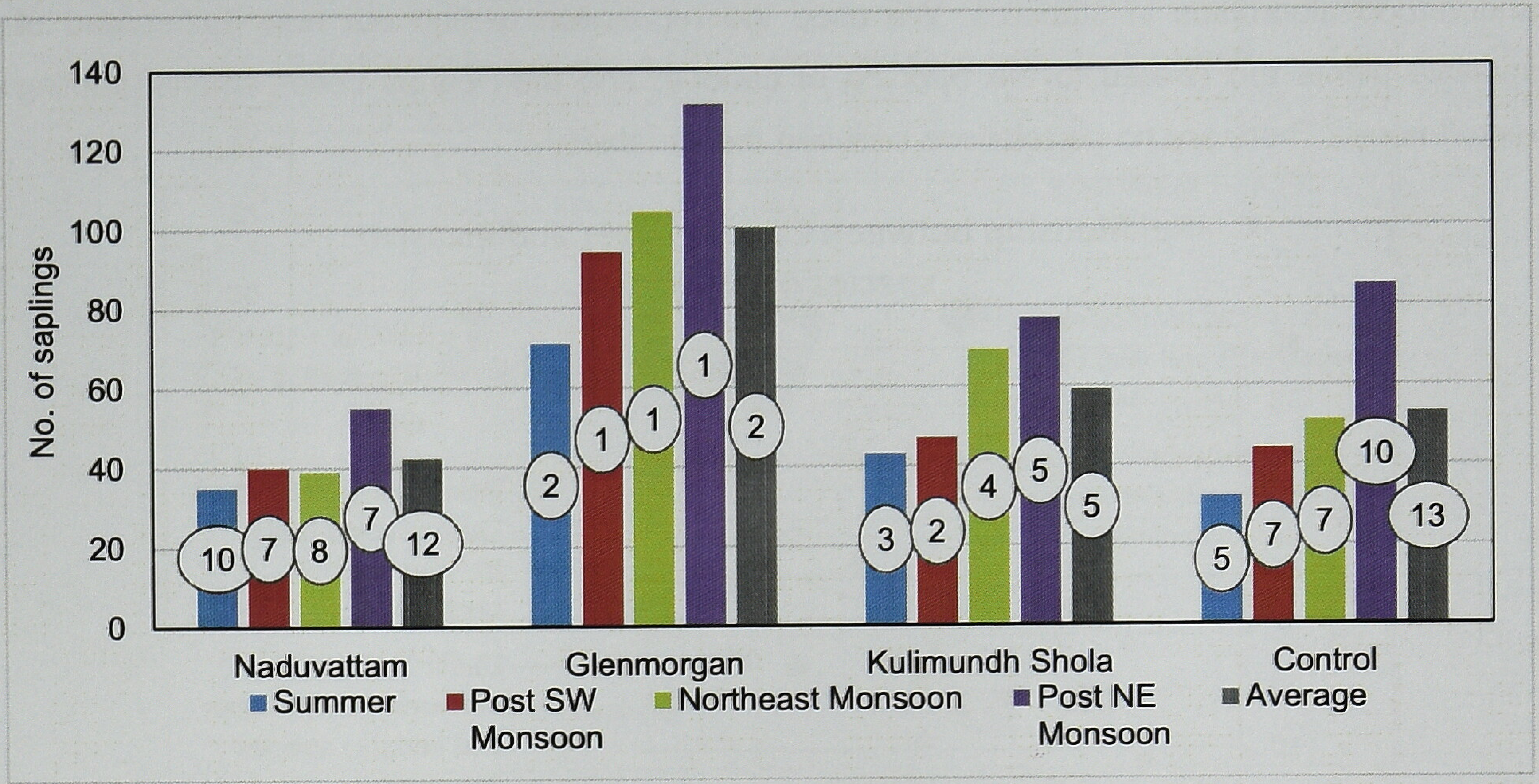


Figure 10: Number of saplings recruited after IAS removal in montane habitat

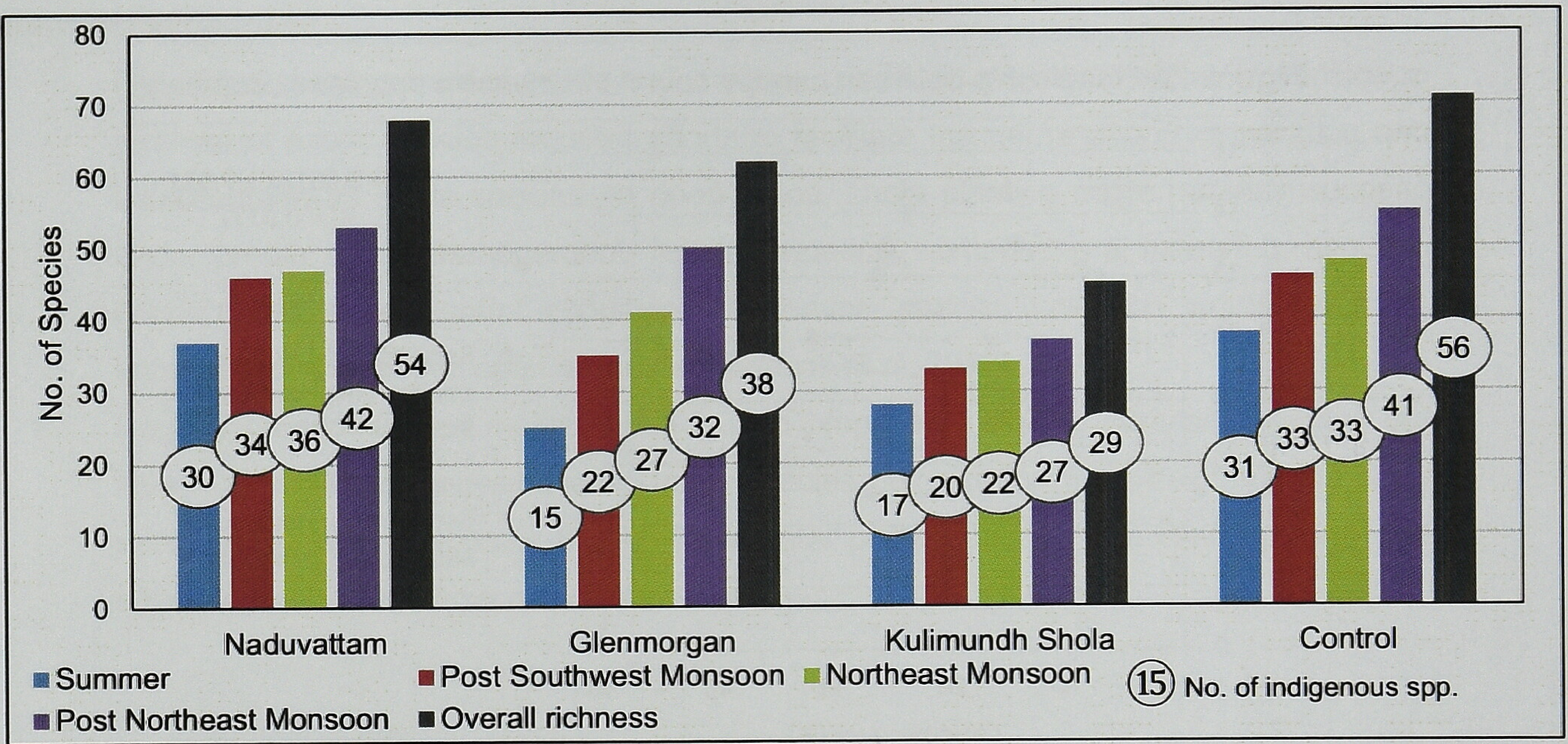


Figure 11: Species richness recorded in montane habitat

Relationship between canopy cover and invasive spread

The short-term study yielded no significant relationship between the invasive plants spread and canopy cover. Linear Regression is a linear approach to establish the relationship between a dependent variable and an explanatory variable using a straight line. It is one of the most understood algorithms in statistics. We used the regression to find out how the spread of invasive plants are related to the opening of canopy; and then canpy cover against sapling recruitments. There are no correlations between the variables.

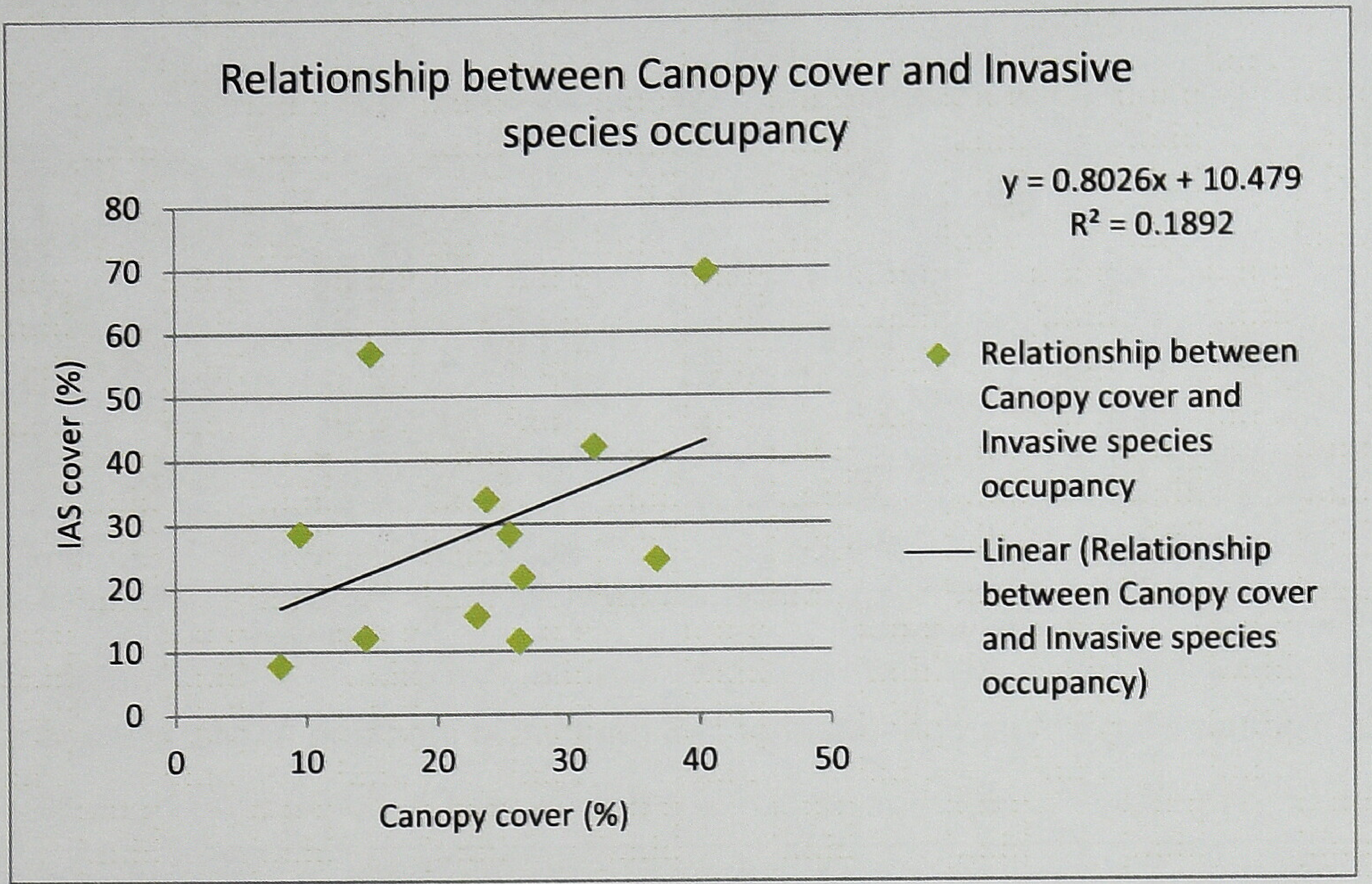


Figure 12: Relatioship between canopy cover and invasive species occupancy

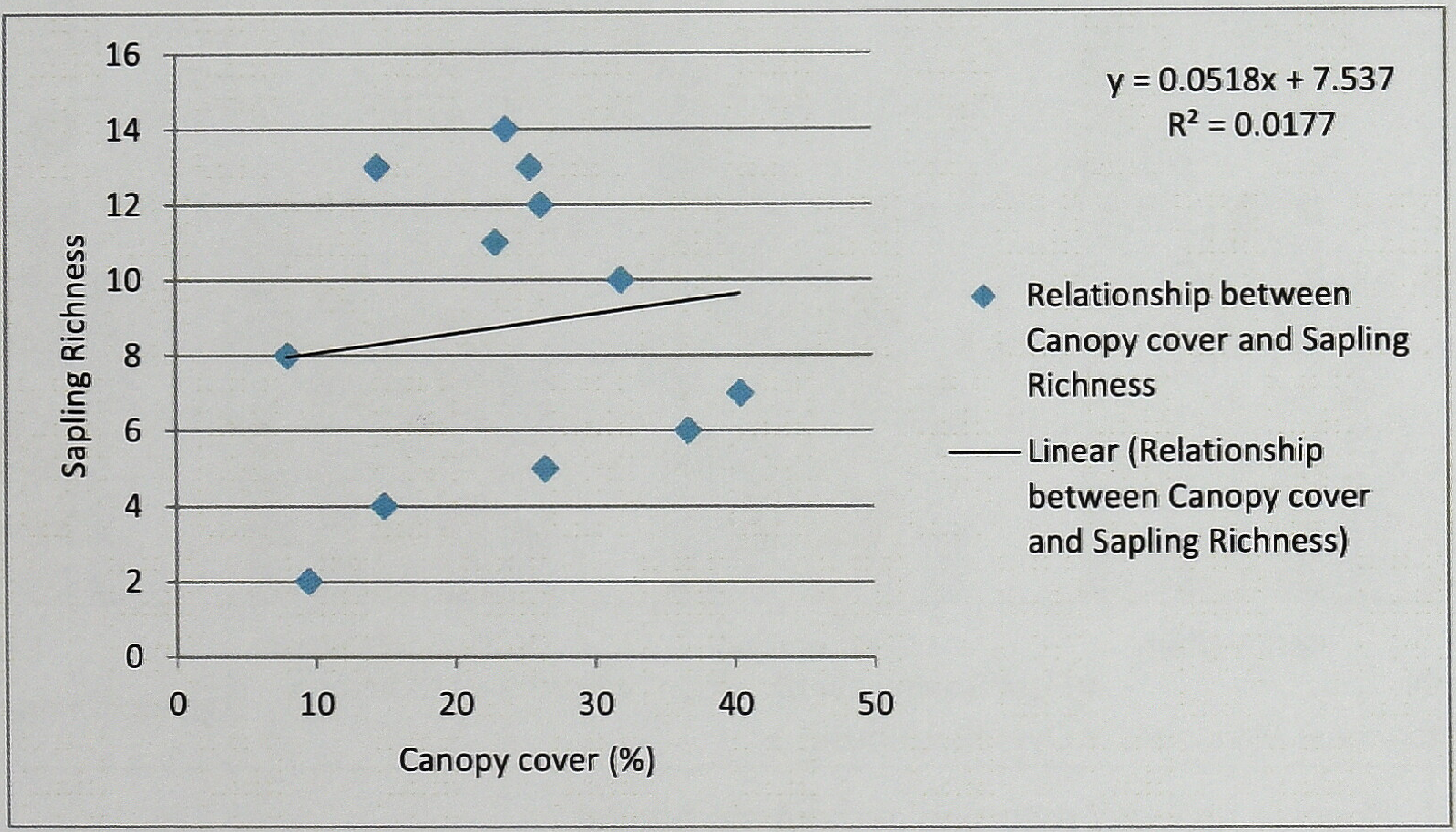


Figure 13: Relationship between canopy cover and sapling richness

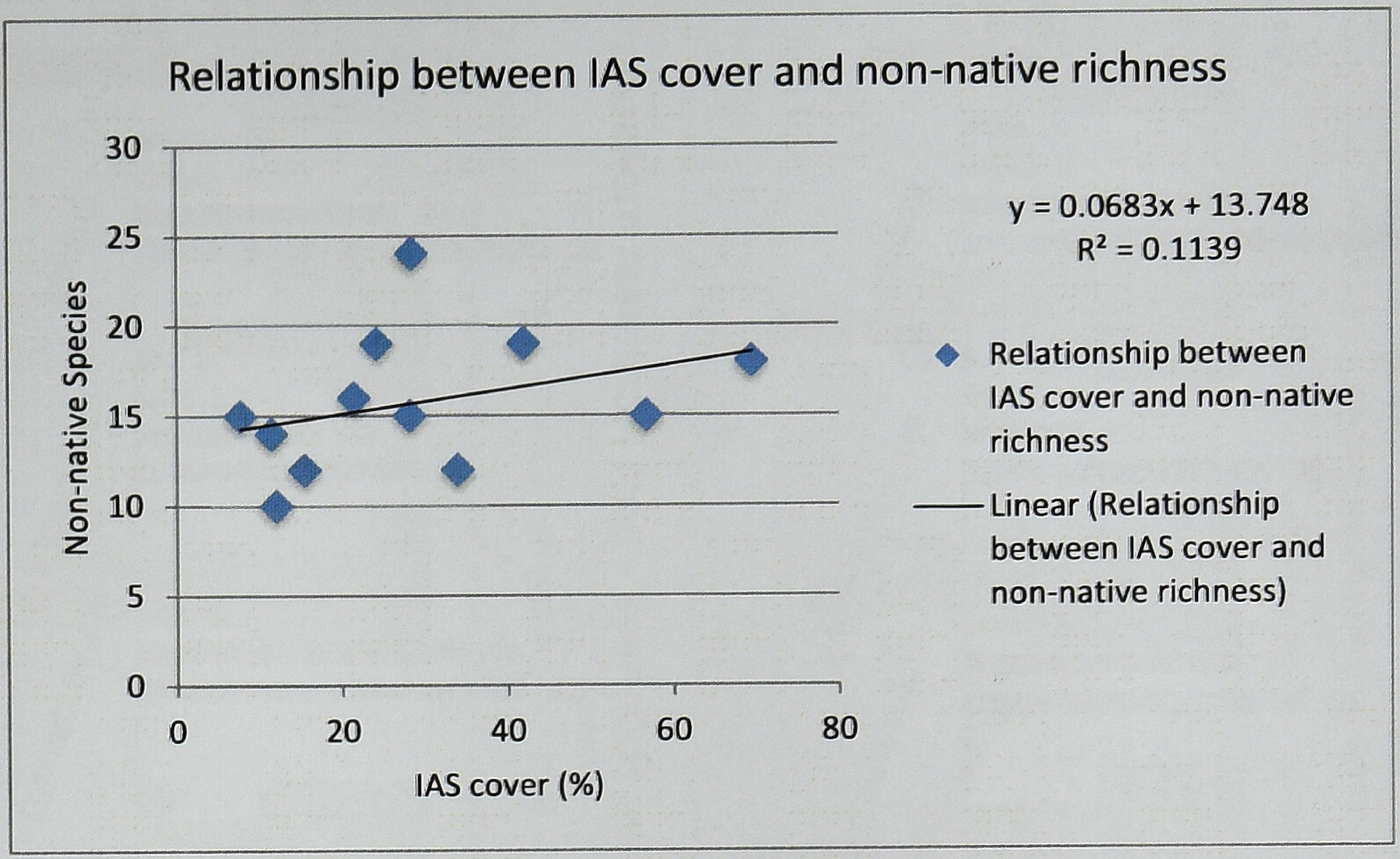


Figure 14: Relationship between canopy cover and non-native richness

Recommendations

i. For proper management of exotic and invasive species in montane habitat, in addition to removal of exotic species required efforts to facilitate the germination/regeneration and establishment of shola species. In open areas, shola planting might possibly succeed under proper shade management, regular watering, composting & manuring, avoiding grazing and weed control conditions. Moreover, species selection would be more important for planting in open areas (Mohandass et al. 2016).

ii. Regular monitoring and maintenance is also proposed including constant weeding the invasive recruits. This would encourage species colonization from neighbouring seed pools, and also incorporate the environmental preferences of dominant species and species associations from neighbouring patches.

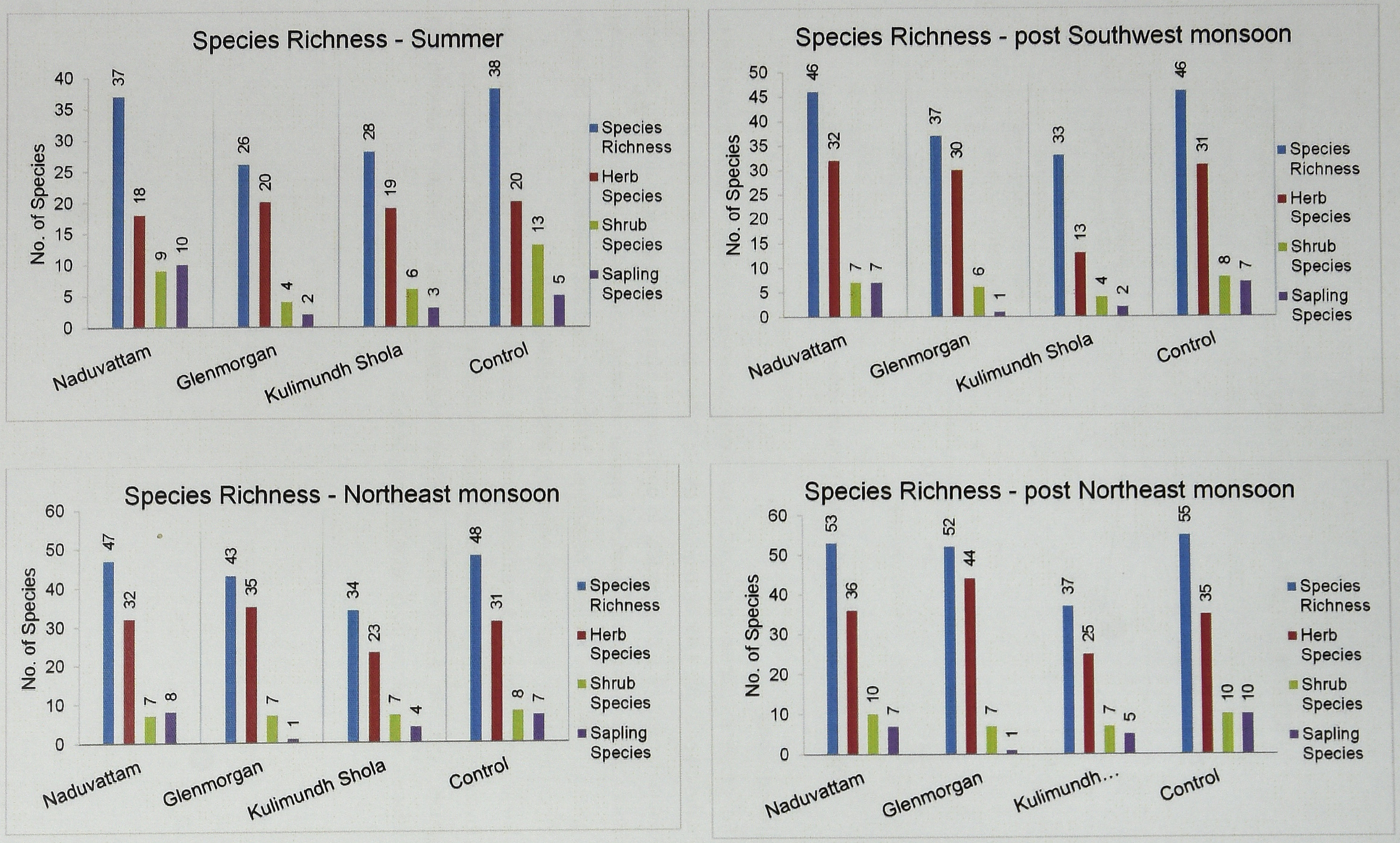


Figure 15: Species richness recorded across all the seasons in montane habitat

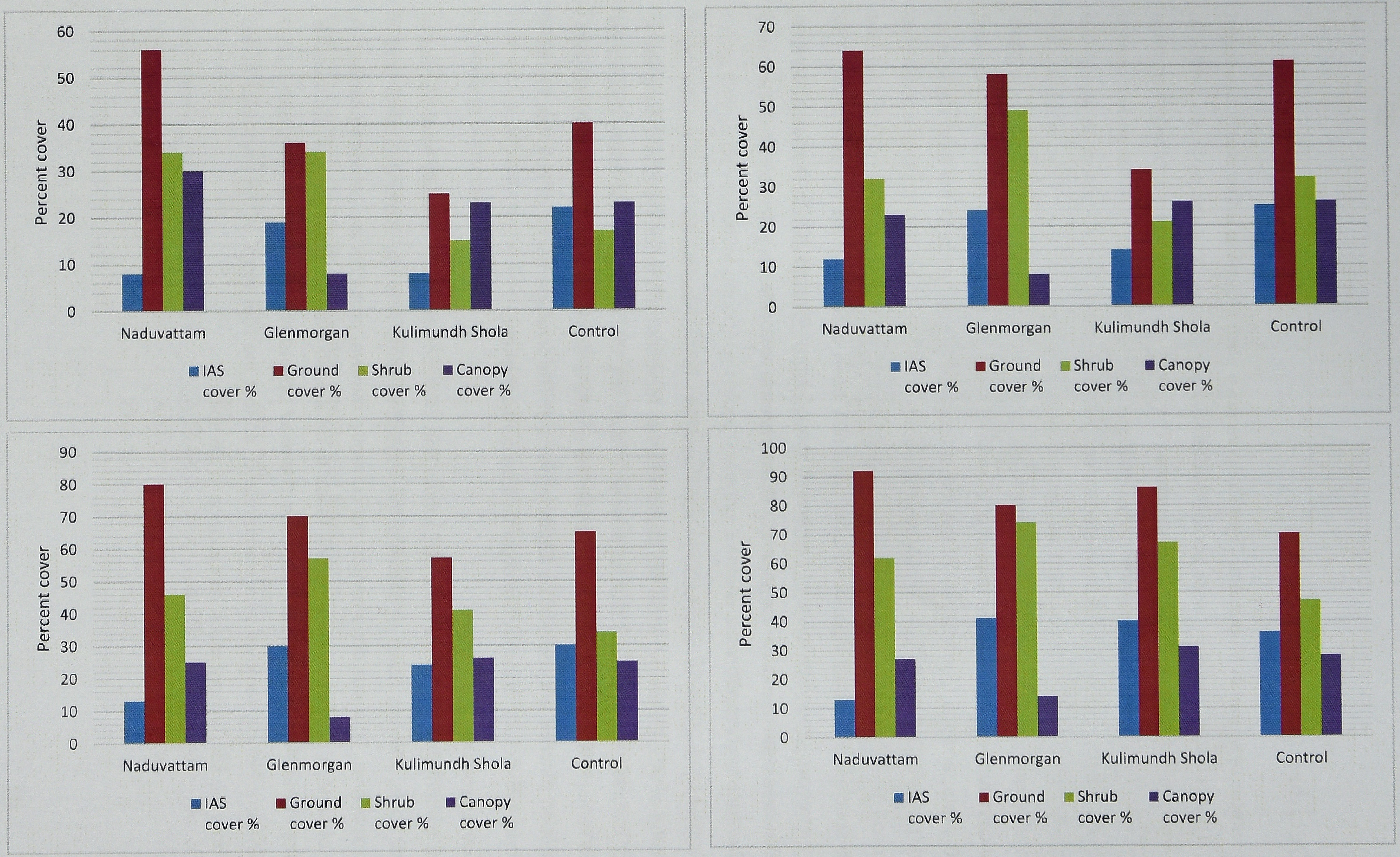


Figure 16: green cover across all the seasons in montane habitat

2. Deciduous Habitat

Four sample plots laid in Mudumalai Tiger Reserve have been classified under deciduous forest type. The data from the plots were pooled and analysed; revealing that the plots are similar in their species composition, and stand structure. The plots represent mature forests that have been under silviculture operation for many decades (beginning with the Colonial period). Large trees of this patch of forest were harvested extensively during the Colonial period, as well as the period that can be broadly labelled as immediate post-independence. These constitute the patches where Dr. Cleghorn made his iconic statement about the pace of forest denudation. Local communities state that the impact of invasive plants has been strongly felt only for the last 15-20 years, and the high visibility of the forest floor which was typical to the landscape is no longer present. Deciduous forests of Mudumalai were once dominated by tall grass species like *Themeda* and *Cymbopogon* as its ground vegetation, along with other taller herbaceous and shrub species; all these indigenous plants have now been overrun by the invasive plants. The area has above-ground-biomass of *Lantana* of about 5 kg/m^2 (Prasad 2012). The target species for this area are: ***Lantana camara*** L., ***Chromolaena odorata*** (L.) King & Robinson and ***Parthenium hysterophorus*** L.

The following diagram is a schematic representation of the deciduous forest typified by a profusion of IAS. Evidently, while the standing trees represent the forest type, and comprise a mix of naturally occurring and planted species (Table 16), the undergrowth is totally dominated by the invasive species. Ground-cover under the shade is dominated by *Chromolaena odorata*, while open patches are overrun by *Lantana camara*. The average height of both the plants is less than two meters, and they are organized as dense thickets.

Removal process

It was evident that the shrub habit of *Lantana* and *Chromolaena* was carefully removed using regular tools. Mowing down or slashing the vegetative parts requires immense labour and is thus expensive. This was done earlier, but currently, removal protocols are being regularized. A point of serious concern is that the soil tends to be loaded with the seed bank of the invasive species, which when disturbed, exposes them to optimal conditions and facilitates faster germination. Hence, removal was standardized, so that the root stock of the plant was pulled over from the soil, without much disturbance to the soil.

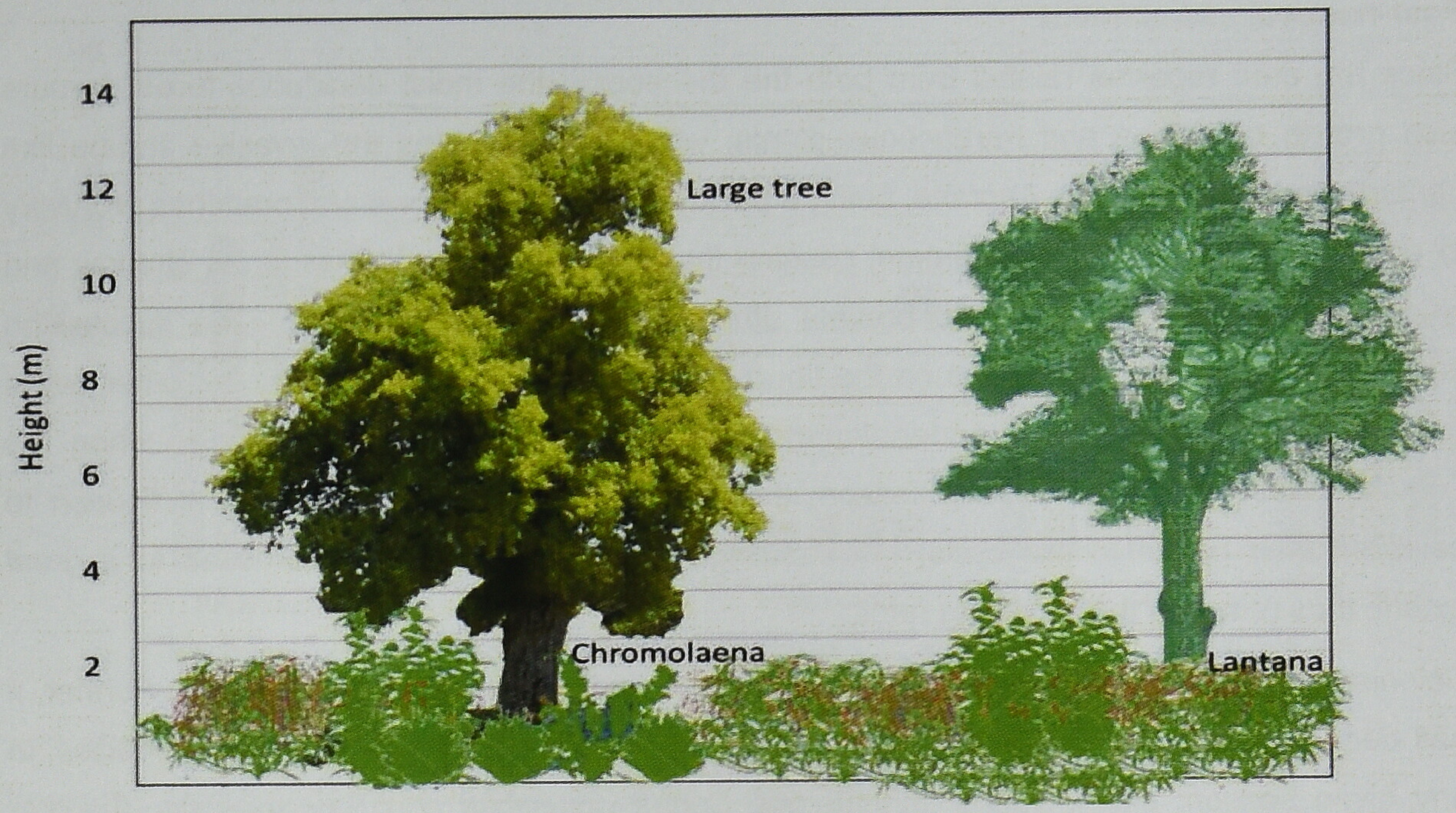


Figure 17: A schematic representation of the deciduous forest affected with IAS

Removal is also season specific. For *Lantana* and *Chromolaena*, the operations were held during their peak vegetative period, *i.e* before flowering. *Lantana* starts flowering profusely from August until March; whereas, the Siam Weed (*Chromolaena*) starts flowering from December unitl May. Wherever there was a delay or a slipup in uprooting the *Lantana* shrub, the plant regenerated profusely; and it is important to note that slipup also includes improper uprooting. The remnants after removal were allowed to sun dry and later heaped in small bunches to incinerate. Care was taken enough to separate the burning remnants from the live vegetation. This was a difficult task in field, but was carried out with maximum possible scrutiny to avoid problems in consecutive years.

The following table present data obtained from the Tamil Nadu Forest Department on the financials for removal and an approximate extent of invasive cover.

Table 6: Operation details in selected patches of Mudumalai TR

Forest Range	Total area affected (%)	Area (Ha.)	Year of removal	Amount spent per Hectare (INR)	Maintenance	
					1st year	2nd year
Masinagudi	60	22	2012-2013	16,500	Yes	No
Masinagudi	60	22	2012-2013	16,500	Yes	No
Teppakaadu	65	25	2014-2015	16,500	Yes	Yes
Kargudi	50	10	2014-2015	16,500	Yes	Yes

Post-removal assessment

Since the area receives rainfall from both the monsoons, the moist deciduous forest favours lush growth of shrubs and herbaceous plants; which also includes the invasive shrubs like *Lantana* and *Chromolaena*. *Lantana*, being a prickly woody shrub grows and branches profusely to entangle any large bodied mammal passing through. The dense thicket forms shadow and blocks the sunlight on ground to prevent other indigenous plants' growth. The succession ensuing next year will leave gaps on the floor; this opening has been used by the other set of invasive plants such as the tender-stemmed *Chromolaena* and *Parthenium*. So, when the *Lantana* dries out during the dry season, the plants that were sheltered under it flourish to establish their niche. In this cycle, the seedlings of native trees are suppressed to a great extent, thus reducing the recruiting rates.

Colonisation by the invasive shrubs is also a threat to indigenous herbs and grasses. Further, it has been observed that the landscape is always dominated by successive invading species, in any given season; that includes annuals like *Senna obtusifolia* and *S.occidentalis*. In other words, the recurrent and dominant presence of Invasive Alien Species in the landscape impacts indigenous plant diversity directly and encroaches upon the habitat of the fauna typical to the landscape.

The importance value index calculated from the relative density and relative dominance of woody species shows that Teak (*Tectona grandis*) dominates the forests. It has also been observed that there is a high mortality rate in trees, showing up dead stands; this is especially with the case of Teak.

In the deciduous forest plots of Periyakulam, Maanboard, Teppakadu and Kargudi, the invasive species including *Lantana*, *Chromolaena* and *Parthenium* were removed by uprooting the plants. Removed *Lantana* was burnt in piles in Kargudi and in some plots in Periyakulam. In the deciduous forests high invasive species cover was recorded in both Periyakulam and Maanboard plots in comparison to control plot. Lower coverage of invasive species was observed in Teppakadu plots relative to control plot; while it was comparable to control plot in the case of Kargudi.

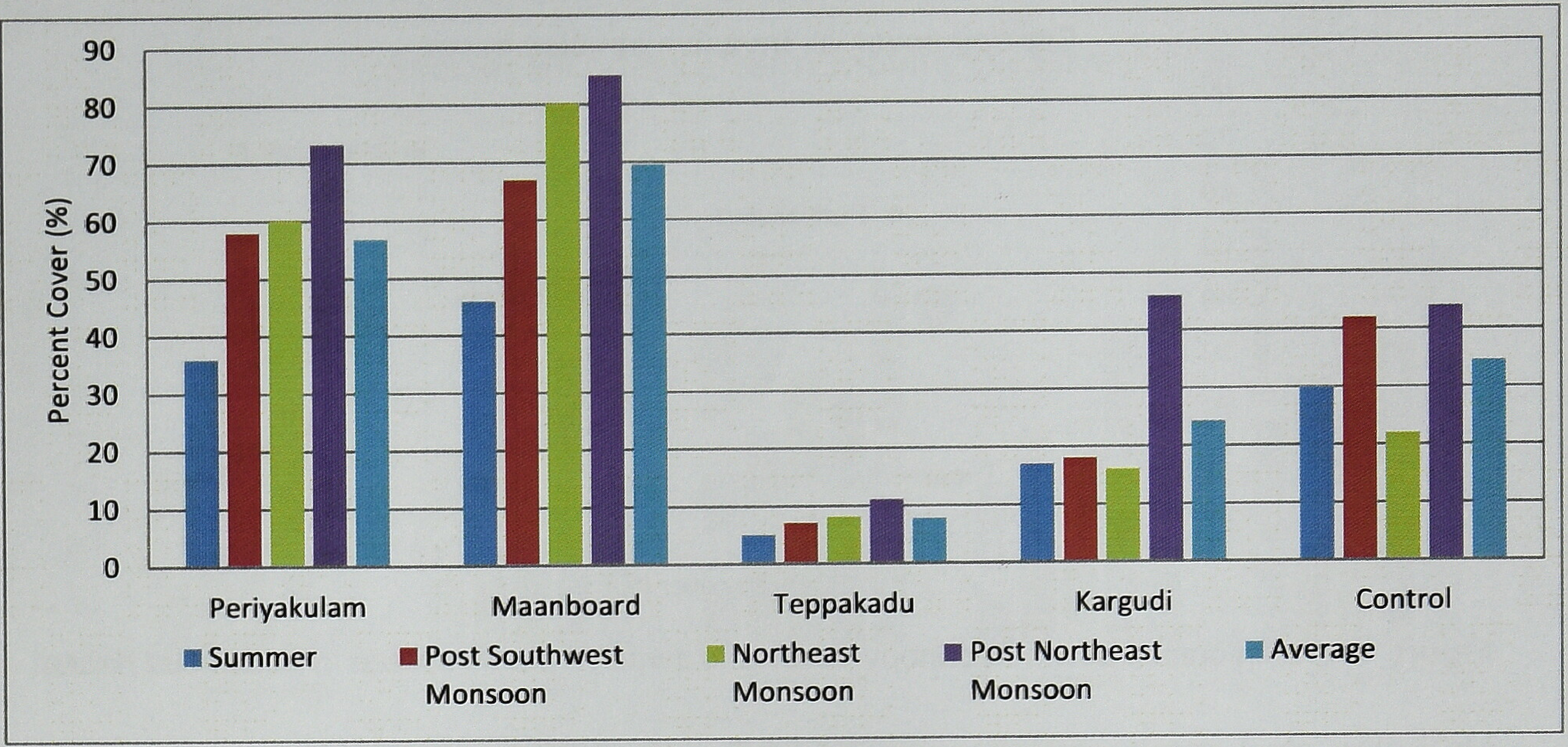


Figure 18: Percentage invasive species cover in deciduous habitat

It was observed that in Periyakulam plots, though *Lantana* was removed, in many areas roots were regenerating and recoppicing from slashed branches that had fallen on the ground and from the base of uprooted clump. On the other hand, the forest is dense in Maanboard, which made removal of invasives difficult. For the same reason, burning of removed invasive species was avoided in Maanboard.

In Teppakadu, the number of invasive saplings was low as the maintenance of plots post-removal of invasive species has been more regular as the region houses a camp for elephants. The camp elephants regularly graze and browse in the area, thereby keeping a check on new invasives. In the case of Kargudi, a cart road passes through the plots which is used regularly for patrolling; thereby, making the area prone to high disturbance and spread of invasive species. Overall, amongst all the plots, the percentage of invasion was highest during post-NEM season, followed by post SWM season and lowest during summer season.

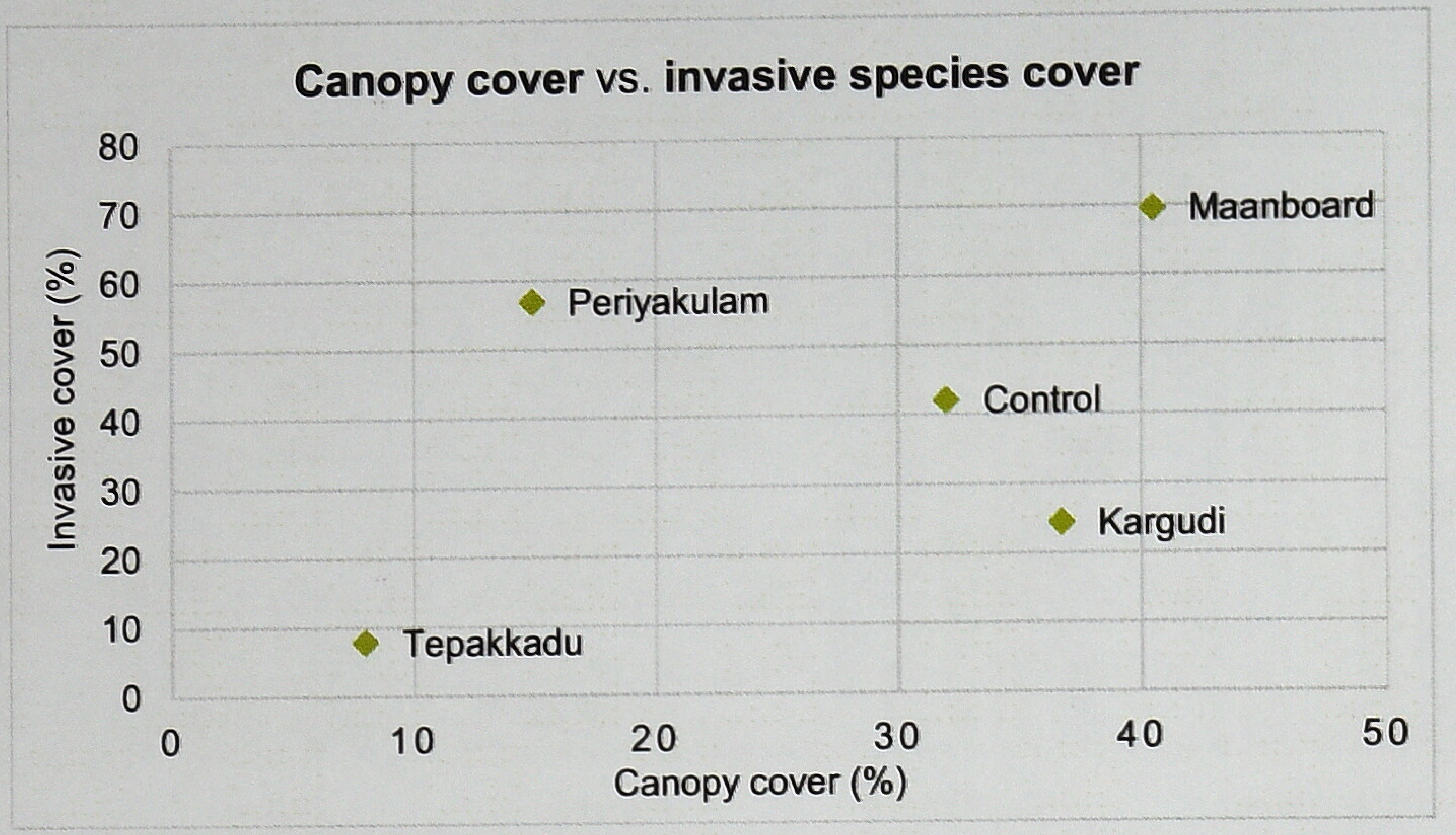


Figure 19: Relationship between canopy cover and invasive plants spread in deciduous habitat

Most alien plant species prefer open-habitats. Therefore, at the site scale, canopy openness should favour the germination and growth of alien species, and at the landscape scale the presence of open habitat should increase the seed rain and therefore the colonization rate of forest sites by alien species (Charbonneau & Fahrig, 2004). To analyze the impact of canopy cover on re-invasion of the sample plots, canopy cover was plotted againt invasive species cover. It was found that in the case of plots in Periyakulam, lower canopy cover favoured high invasive growth. However, in the case of Maanboard, despite having high canopy cover, very high invasive growth was recorded. Only in the case of Kargudi and control plots, high canopy was recorded with low invasive growth.

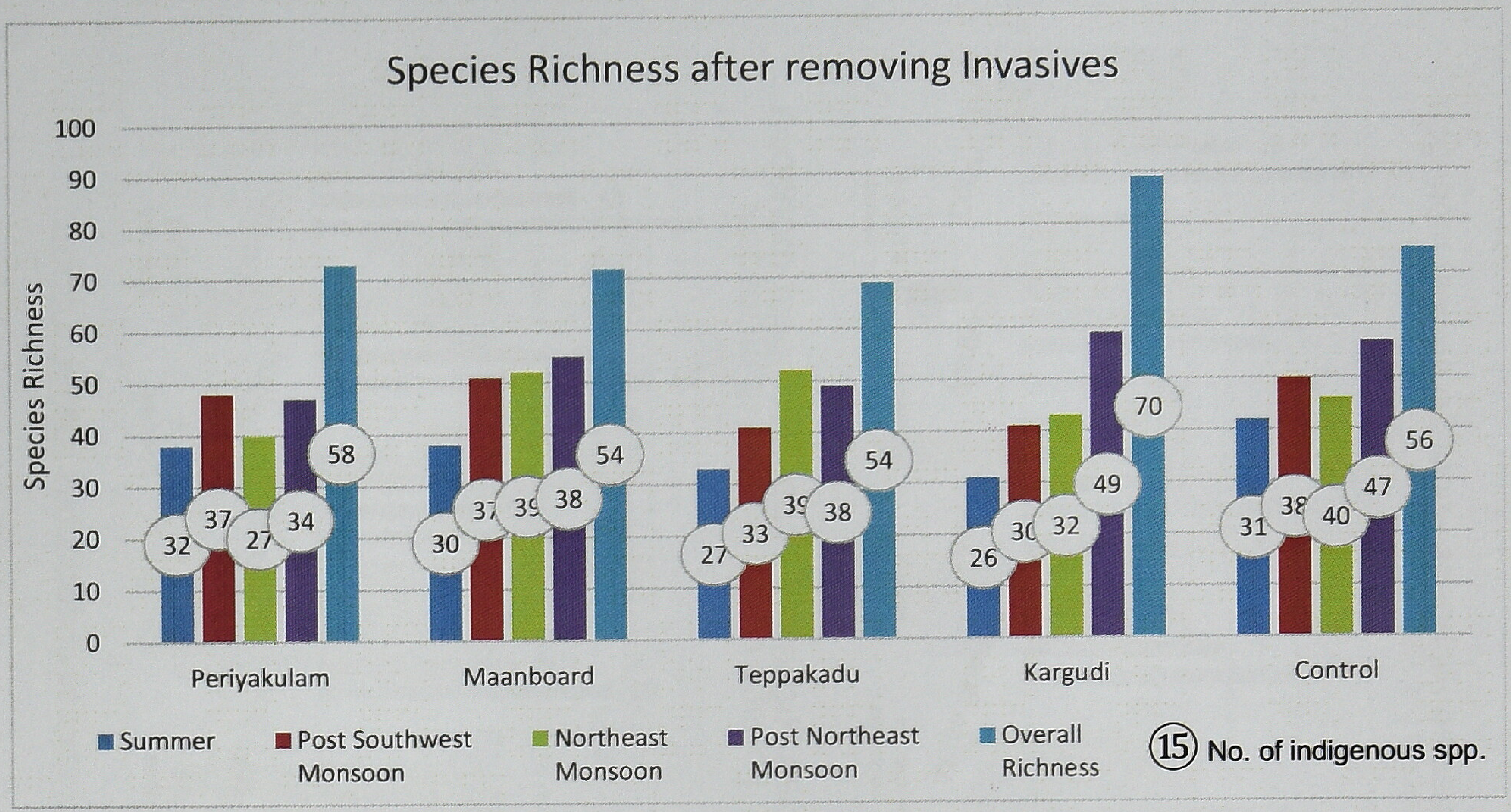


Figure 20: Species richness at plots of deciduous habitat

Overall, the species richness was recorded to be lower than the control plots in all the plots located in Periyakulam, Maanboard and Teppakadu; while it was comparable to control in Kargudi plots. Comparing species richness across seasons, high species richness was recorded during post monsoon seasons (both SWM and NEM) in all the plots, in comparison to summer season, as rainfall promotes seed germination and plant growth. Further, it was observed that during the summer season, the richness of indigenous species was higher in all the plots where invasive species had been removed in comparison to the control plots; while it was lower during the post NEM season. Comparison of species richness across the plots showed that Kargudi plots had the highest species richness, followed by Periyakulam, Maan board and Teppakadu.

Since, the evaluation was carried out 4-5 years after the removal of invasive species, a significant increase in these plots in comparison is not recorded. Further, as no efforts were made to re-establish native communities, the species richness did not increase considerably.

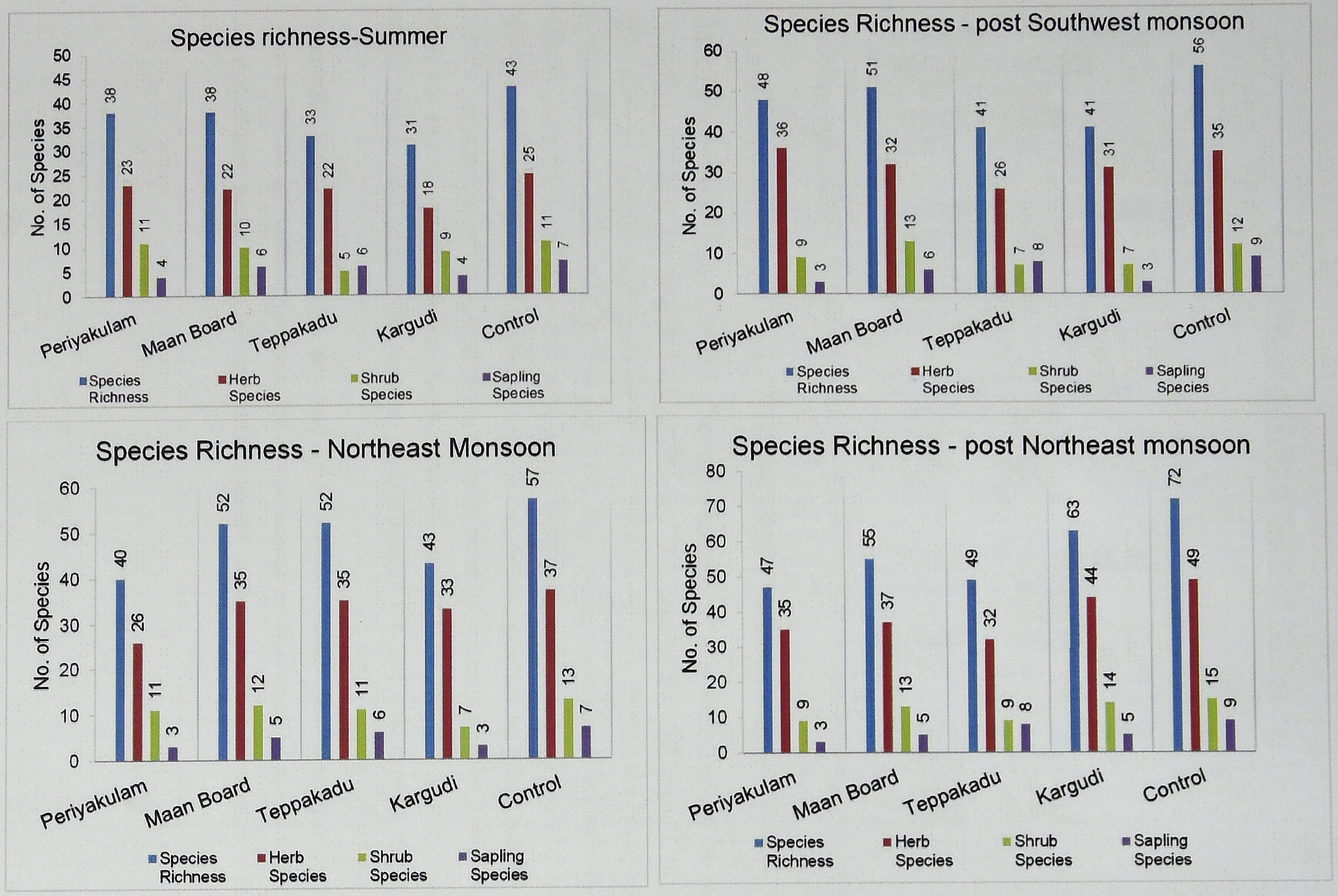


Figure 21: Species richness of herbs, shrubs and sapling species in deciduous habitat

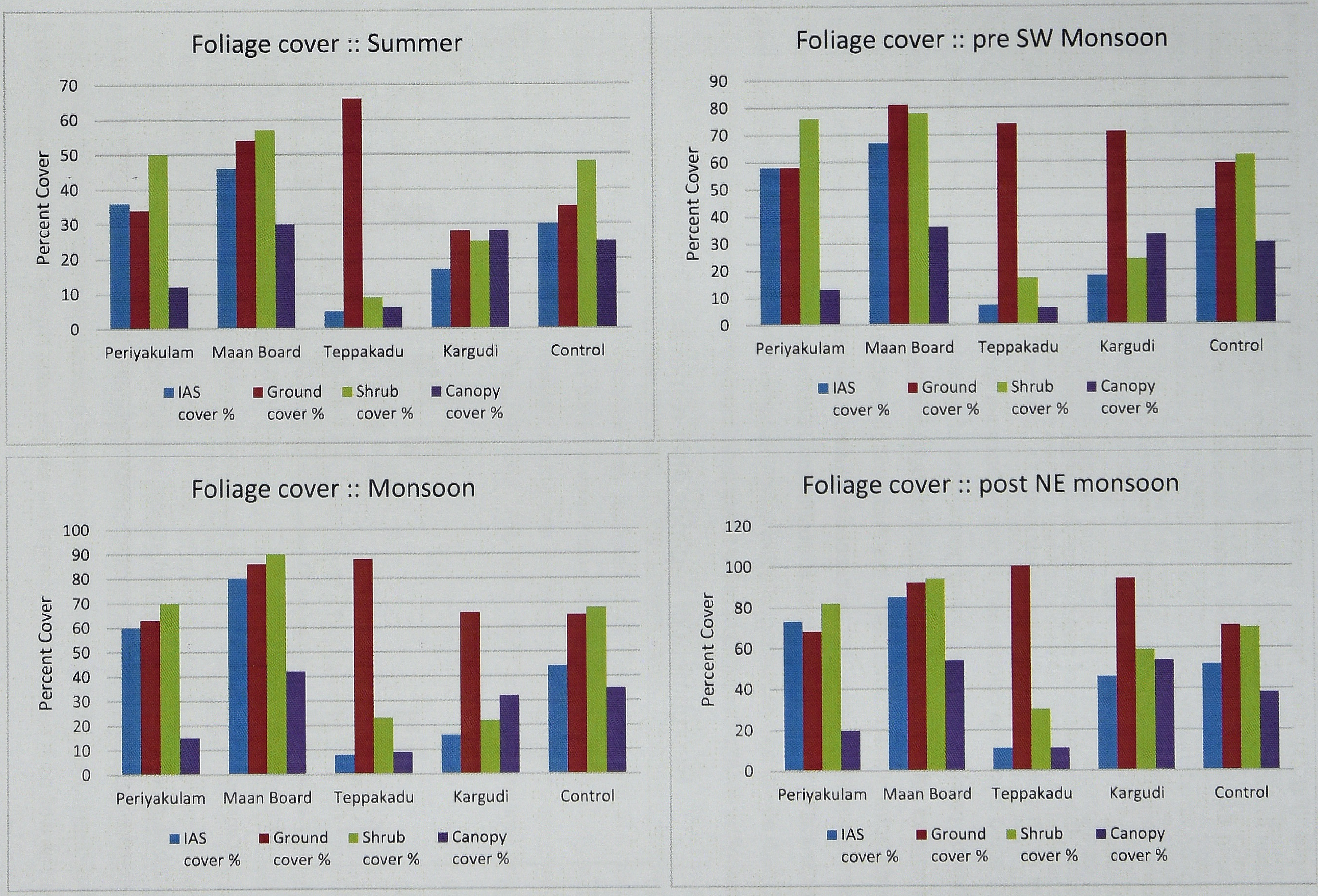


Figure 22: green cover in plots of deciduous habitat

The graphs (Fig.21) show higher species richness in the case of herbaceous species in comparison to shrubs in all the plots across all seasons especially monsoon and post-monsoon seasons. In this case, the increase in local species richness associated with invasive species clearing occurred mainly due to the expansion of herbaceous species (e.g. with a good colonizing ability) that could take advantage of open conditions newly encountered in managed microhabitats.

In addition, the elimination of invasive species, which are piled and burned, also decreased the amount of litterfall in shrub-cleared treatments. On one hand, the higher radiation at the soil surface could favour the colonization of new herbaceous species, either through seed dispersal from nearby patches or by stimulating germination of persistent soil seed banks. This trend of higher species richness with increasing light availability at the forest floor has been documented in other studies. On the other hand, the thicker litter layer found in unmanaged stands might reduce colonization rates of herbaceous plants, likely through inhibition of seedling establishment by shading and physical obstruction. Moreover, the reduced litter accumulation also could affect soil nutrient availability and interactions with soil micro-organisms, thus influencing the floristic composition of the forest understorey (Perez-Ramos et al. 2008).

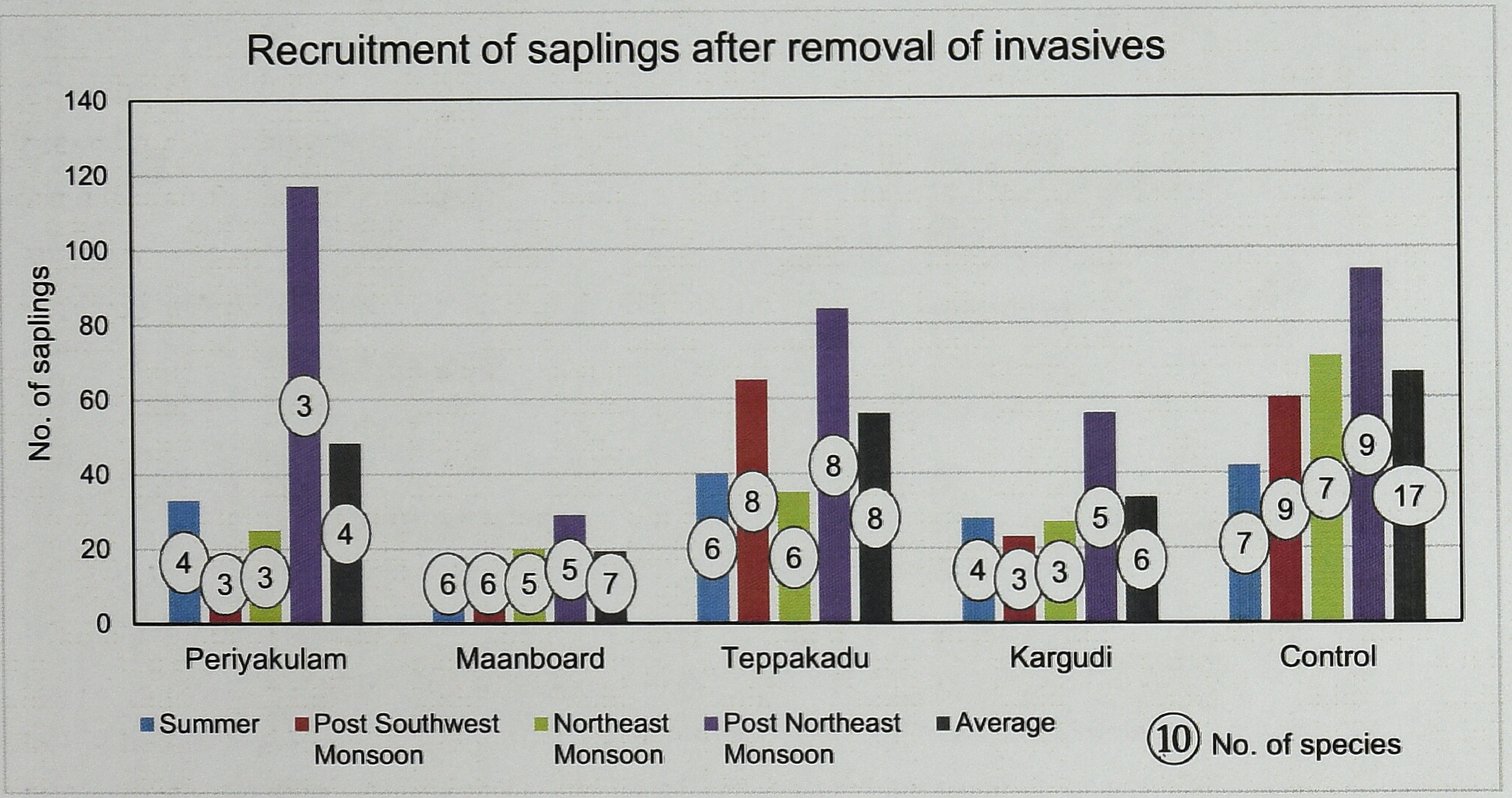


Figure 23: Number of saplings recorded at plots in deciduous habitat

Analysing the recruitment of new species across seasons, highest number of saplings were recorded during post NEM season in all the sample plots where invasive species had been removed as well as in control plot. Amongst the sample plots, highest recruitment was recorded in Periyakulam followed by Teppakadu, Kargudi and least in Maanbord. However, the number of species to which these saplings belonged was not very high in Periyakulam. The number of newly recruited species was highest in Teppakadu (8), followed by five each in Kargudi and Maanboard and lowest in Periyakulam. This shows that high number of saplings established in Periyakulam belonged to few particular species- *Butea monosperma, Dalbergia latifolia* and *Tectona grandis*. Teak and Dalbergia saplings were recorded in all the plots; while *Cassia fistula* saplings were recorded in Maan board, Teppakadu and Kargudi plots. Saplings of these species indicate regeneration of tropical moist and dry deciduous forest tree and understorey species (Suresh and Sukumar, 1996).

The three primary invasive species (species which were targeted for removal) - *Chromolaena odorata*, *Parthenium hysterophorus*, and *Lantana camara* were recorded in all plots post removal. *Chromolaena* sp. was considered as harmless during 1870s; whereas the Lantana had already invaded the peninsular India at that time. J.D.Hooker in his flora treatise (Flora of British India, 1881-1897) had considered this *Chromolaena* as suppressed species. Studies have shown that positive interactions between exotic species may increase ecosystem-level impacts and potentially facilitate the entry and spread of other exotic species. Invader-facilitated invasion success—"secondary invasion" was recorded in the present case. Secondary invasion by *Senna uniflora* and *Ageratum conyzoides* was recorded in all the plots during the monsoon seasons. These secondary invasives were however, absent in the sample plots during summer season. In Maanboard plot, in addition to the two secondary invasive species, growth of *Aeschynomene americana* was also recorded. The latter herb is an aggressive colonizer escaped from agricultural fields.

Recommendations

a. Lantana removal

Amongst the three invasive species targeted- *Lantana, Chromolaena* and *Parthenium*, re-invasion by *Lantana* was recorded to be highest in all the sampled plots. The most common methods used in India for the control of *Lantana* in forests are: (i) Hand pulling, (ii) Slashing / chopping of the stems, (iii) Burning, and (iv) Manual Grubbing with substantial removal of the root system. These methods have had no or little effect in controlling the spread of *Lantana* infestation, due to their inherent limitations and absence of an integrated control strategy. Some of these methods such as slashing/chopping and burning of Lantana clumps have actually led to the further worsening of the infestation; and in some areas, burning of the weed has promoted its spread to new areas.

Manual grubbing, as was done in the present case, involves both slashing of branches of *Lantana* clumps to be removed and extensive digging of root system of the slashed *Lantana* clumps. There are two major disadvanges of this method: (i) due to extensive digging below the Lantana clump, the soil is extensively disturbed leading to exposure of buried Lantana seeds to light which leads to gregarious germination and establishment of seedlings, (ii) regeneration and recoppicing from slashed branches that are fallen on the ground and from the base of uprooted clump; regeneration also takes place from the rooted prostrate branches that might have been severed from the clump while grubbing. Mechanical grubbing results in extensive loosening of soil leading to enhanced soil erosion and also large-scale germination of Lantana seeds; it also disturbs the native plant species established between clumps.

Studies suggest the following integrated method of Lantana removal-

i. Sites for removal of *Lantana* should be identified through field surveys using the data collected on the extent/ magnitude of infestation and density of *Lantana*. The *Lantana* removal operation should follow the 'inside-out' method wherein *Lantana* is removed first from areas with maximum *Lantana* density and then moving outwards along a decreasing *Lantana* density gradient. In areas having undulating terrain and hilly tracts *Lantana* removal operation should be taken up on the slopes first and then downwards to the valley.

ii. The removal operation should be done preferably at a time when a majority of the *Lantana* clumps are not in flowering or fruiting stage.

iii. One of the innovations in the new management strategy is the development of a simple and cost-effective manual method for the removal of *Lantana*, known as **cut rootstock method.** It involves cutting the main tap root of *Lantana* plant beneath the 'coppicing zone' (transition zone between stem base and rootstock). This method of removal involves the engagement of 2–3 individuals to work in a group for the removal of *Lantana* if the clump is large enough that it cannot be handled by one individual after the rootstock is cut. The steps involved in the cut rootstock method are: (a) The person, who engages in removal of *Lantana*, is positioned in a way that he stands near centre of the *Lantana* clump with his back facing the clump and holding the handle of digger. (b) Using the specially designed digger, the person cuts the main rootstock of *Lantana* 3–5 cm below the soil surface by hitting the rootstock 3 or 4 times; while hitting the rootstock the blade of the digger gets lodged into the main tap root, and at this point it is useful to move the handle of the digger in the forward direction away from the body of the person so as to severe the connection of the clump with the main tap root. In case the clumps of

Lantana form impenetrable thickets, it is advantageous to cut the rootstocks of 3–4 contiguous clumps to make the removal operation convenient. It may be noted that the branches of *Lantana* clumps should not be slashed/cut to gain access to the centre of the clump for its removal by cut rootstock method. branches of *Lantana* thicket formed by more than one clump should be lifted and tipped over from one end by using a wooden or bamboo pole of about 1.5–2.5 m long and diameter 5–6 cm which is inserted just below the branches from one side and rolled over easily by two workers holding the pole at either end and pressing it so as to reach the centre of the clump. Such manual handling of impenetrable thicket is possible because of the umbrella type of canopy which makes it difficult to reach the centre of clump easily. Such physical manoeuvers minimize or prevent regeneration from rooted cut branches when they fall on the ground.

(c) Lift the clump/s and place the clump/s upside down. If the clump is not placed upside down, the prostrate rooted branches and the aerial old branches having aerial roots at nodes may develop into adult plants when they come in contact with the soil. Therefore, the upside– down orientation of cut clumps is critical in the prevention of regeneration of *Lantana* from cut clumps. It may be noted that *Lantana* does not produce root suckers.

(d) After drying the clumps, the clumps may be used as fuel or burnt at the same site or all the dried clumps may be collected at one place and then burnt (Love et al. 2009).

b. Corridors for invasive species

The rapid and high appearance of invasion in plots where invasive species had been removed could be explained by their proximity to the roads. It was observed that all the plots where invasive species were cleared were either close to roads or streams or both, making them open to invasion. Roads can play a profound role in the spread and growth of invasive species by serving as corridors for movement and by providing prime habitat for establishment. Similar to roads, disturbed riparian areas along streams and rivers are also susceptible to invasive species introductions. Seeds, rhizomes and roots, and plant fragments can easily flow downstream during periods of high water and establish elsewhere. It is porposed that particular attention should be paid to infestations that serve as sources for seed dispersal into uninvaded or ecologically sensitive areas. The primary vectors of long-distance dispersal, such as road maintenance activities or vehicular traffic should be identified. Further, the road-edge disturbance should be minimized as these areas provide an ideal seed bed for germination.

c. Restoration

It can be inferred from the above observations that if the invasive-free landscapes are not ecologically restored, reinvasion by *Lantana* or secondary invasion by some other alien weeds (Table 9) such as *Parthenium*, *Wedelia*, *Aeschynomene americana* and *Mimosa* takes place. Therefore, ecological restoration is critical in the management of invasives in the forest ecosystems. For restoration of invasive free landscape, the native bottom–up woody species that process the habitat can be planted along with grass species or can be introduced in a sequential manner. Ecological restoration should be carried out concurrently with removal of invasive species without much of time lag. The species assemblages of grasses and legumes used for ecological restoration vary across the ecological gradients, and thus the species of grasses and legumes selected for restoration are site-, locality- and region-specific (Love et al. 2009).

3. Scrubland Habitat

The landscape is characterized by lower rainfall when compared to the other two types; and consequently, is drier and dominated by thorny plants. Lianas and armed climbers are commonly found dangling over shrubs and trees. Species diversity is less pronounced owing to limited availability of water. Dense thickets of invading species pose a threat to habitat and biodiversity dissipation.

The study reveals a drastic reduction in herbaceous and shrubby species diversity; whereas the trees are unaffected. The target species for removal in this area were Cactus (*Opuntia* spp.), *Lantana*, *Chromolaena* and *Parthenium*. Species composition for this habitat is given in Tables 26 & 27. The dominant presence of *Chloroxylon swietenia* tree and its saplings suggest good presence of indigenous trees.

Efficiency of the removal

The removal of the invasive plants has been carried out in plots that are marked in a linear manner to increase efficiency. Mechanism for removal involved mowing down the Cactus shrubs using earthmoving machinery. This mechanical removal is inevitable as the concerned plant is very prickly and shows dense growth. Manual removal of the *Opuntia* afflicts injuries to labourers and is expensive. The remnants of the mowed plant parts are heaped in small piles for incineration. Since the plant is succulent, invariably a part of the plant body stays on ground.

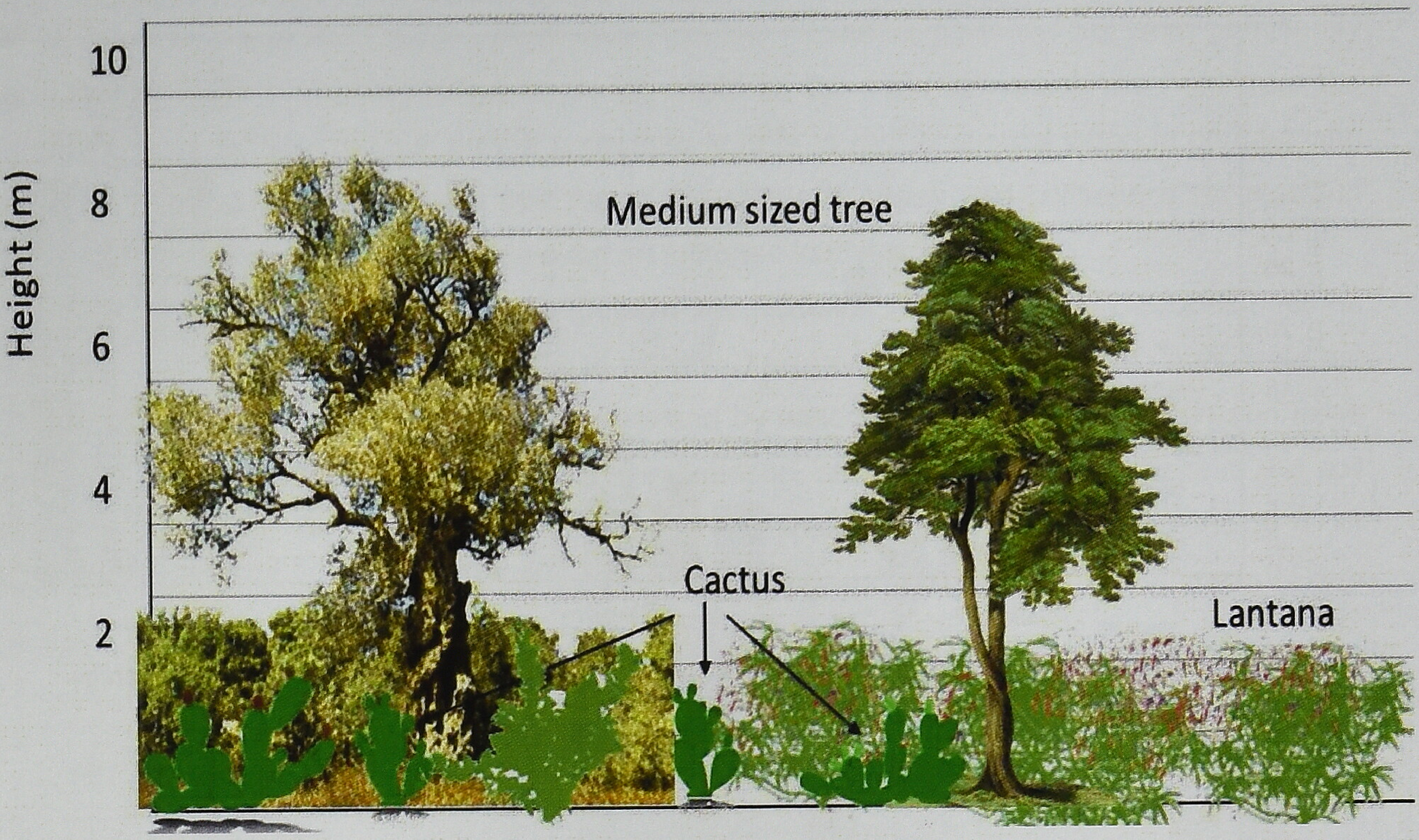


Figure 24: A schematic representation of the scrub forest affected with IAS

Recolonisation of the eradicated species

Vegetative propagation is one of the deciding factors for the invasiveness of some exotics; *Opuntia* is such a plant. The cut-parts or left-overs from the incineration heaps continue the life-cycle by rooting from a vegetative part. This character has diluted the removal process. Further, since the removal has neither been recurrent nor followed up with intensive maintenance effort, the inefficiency of the intervention is exacerbated. Field observations indicate the recovery and recruitment of the invasive species within a couple of years. The following table present data on the operation in selected patches, as also the extent of IAS in the scrub forests.

Table 7: Operation details in selected patches (year: 2013-2014)

Forest Range	Total area (Ha.)	Area operated (Ha.)	Approximate area affected (%)	Amount spent / Ha. (INR)	Maintenance	
					1st year	2nd year
Segur	4195	100	60	6,000	No	No
Singara	5100	90	60	6,000	No	No

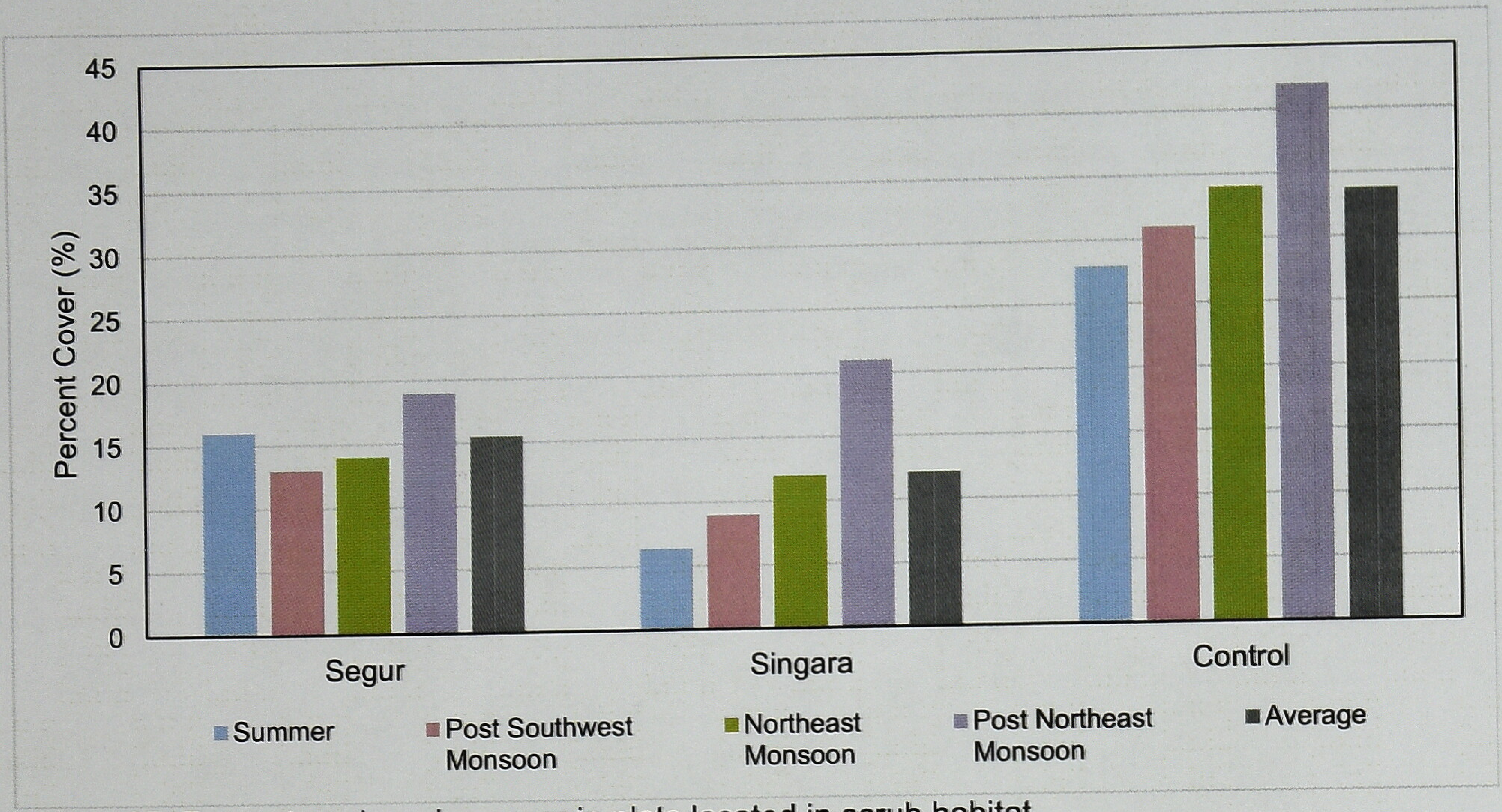


Figure 25: Percentage invasive cover in plots located in scrub habitat

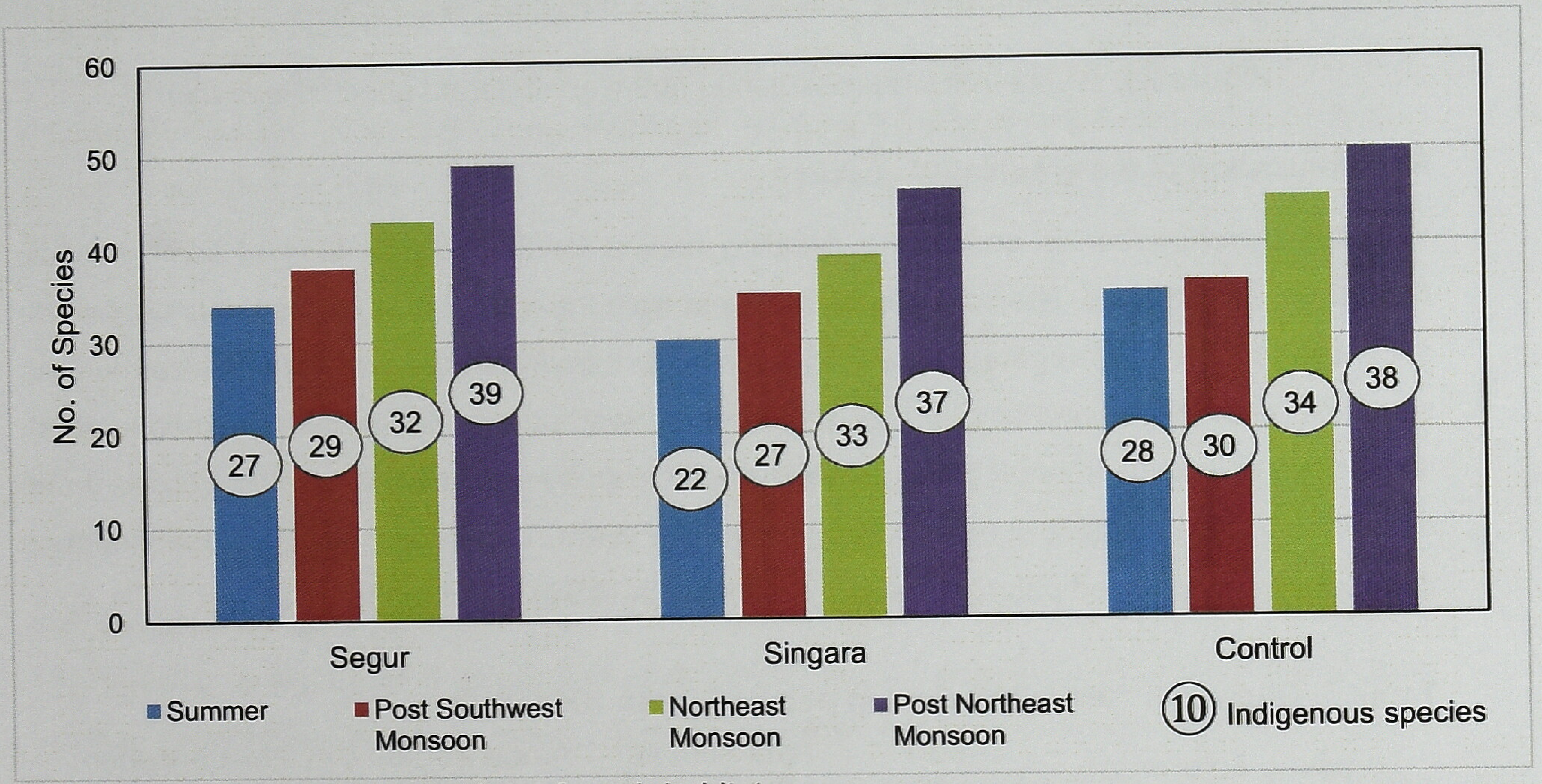


Figure 26: Specis richness in plots of scrub habitat

In the scrub habitat, invasive species including *Lantana, Opuntia, Chromolaena* and *Parthenium* were removed in Segur and Singara. Both Segur and Singara showed high invasive cover post NEM season. Owing to prickly thorns, the removal of prickly Cactus (*Opuntia*) is difficult and hence no complete removal was observed in the sample plots. It was noted that Cactus was removed and piled in one place in the plots, which again started rooting after the rains. Further, in cases where grubbed Cactus was incinerated, the succulent parts did not burn completely and started rooting. The vegetative re-growth could be the main reinvasion mechanism in the treated areas. As the smallest part of a cladode is able to root and grow when in contact with the soil, mechanical disturbances that cause the plants to break and collapse often result in considerable vegetative regrowth and even an increase in invasion.

Opuntia forms dense thickets through vegetative reproduction when detached cladodes become rooted in the ground and have the ability to withstand prolonged drought and high temperatures. The species produce many seeds that are spread by various agents, including birds and large mammals. Germination occurs during the rainy season, although seeds can persist in the soil for many months. In addition, *Opuntia* has relatively shallow and horizontally spreading roots that use water efficiently. Such traits ease its spreading and colonization in dry areas (Githe 2018).

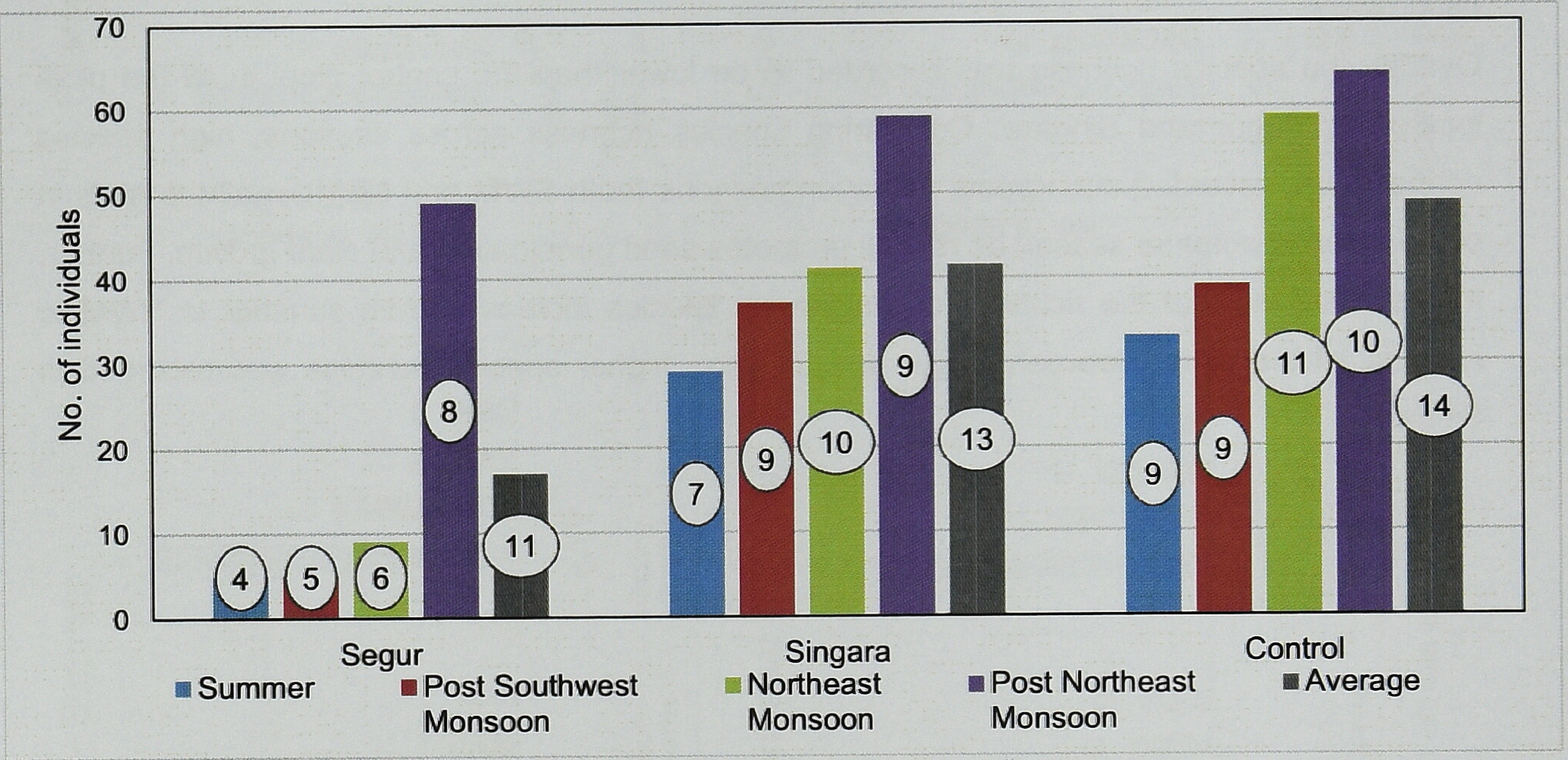


Figure 27: Number of saplings recorded post invasive species removal in scrub habitat

Analysing the recruitment of new species across seasons, highest number of saplings were recorded during post North-east monsoon in all the sample plots where invasive species had been removed as well as in control plot. Amongst the sample plots, high recruitment was recorded in Singara in comparison to Segur. In Segur except for post NEM season, very low number of saplings was recorded across all the other seasons. In terms of number of species to which these saplings belonged, Singara and Segur recorded 13 and 11 species respectively.

While of saplings of *Acacia chundra* were recorded in both Segur and Singara plots, regeneration of *Ziziphus oenoplia, Canthium coromandelicum* and *Capparis divaricata* was recorded only in Singara. Saplings of these species indicate regeneration of Southern Tropical Dry Thorn forest (Suresh et al. 1996).

The four primary invasive species (species which were targeted for removal) - *Opuntia vulgaris, Lantana camara, Chromolaena odorata*, and *Parthenium hysterophorus* were recorded in all plots post removal. Secondary invasion by *Synadenium grantii* was recorded only in plots located in Segur Range.

In comparison to deciduous habitat, regeneration of higher number of species was recorded in scrub habitat. This could be because- (i) *O. vulgaris* is an invasive species not an indigenous species. *Opuntia* spp. does not fix nitrogen or cause an accumulation of leaf litter that can modify the balances of C/N, pH, or flammability; and (ii) the environment is naturally adapted to disturbance.

Overall, the species richness was recorded to be lower than the control plots in all the plots located in Segur and Singara. Comparing species richness across seasons, high species richness was recorded during post monsoon seasons (both SWM and NEM) in all the plots in comparison to summer season as rainfall promotes seed germination and plant growth. Further, it was observed that the richness of indigenous species increased from summer to SWM to NEM in all the plots. Between Segur and Singara, higher species richness was recorded in Singara.

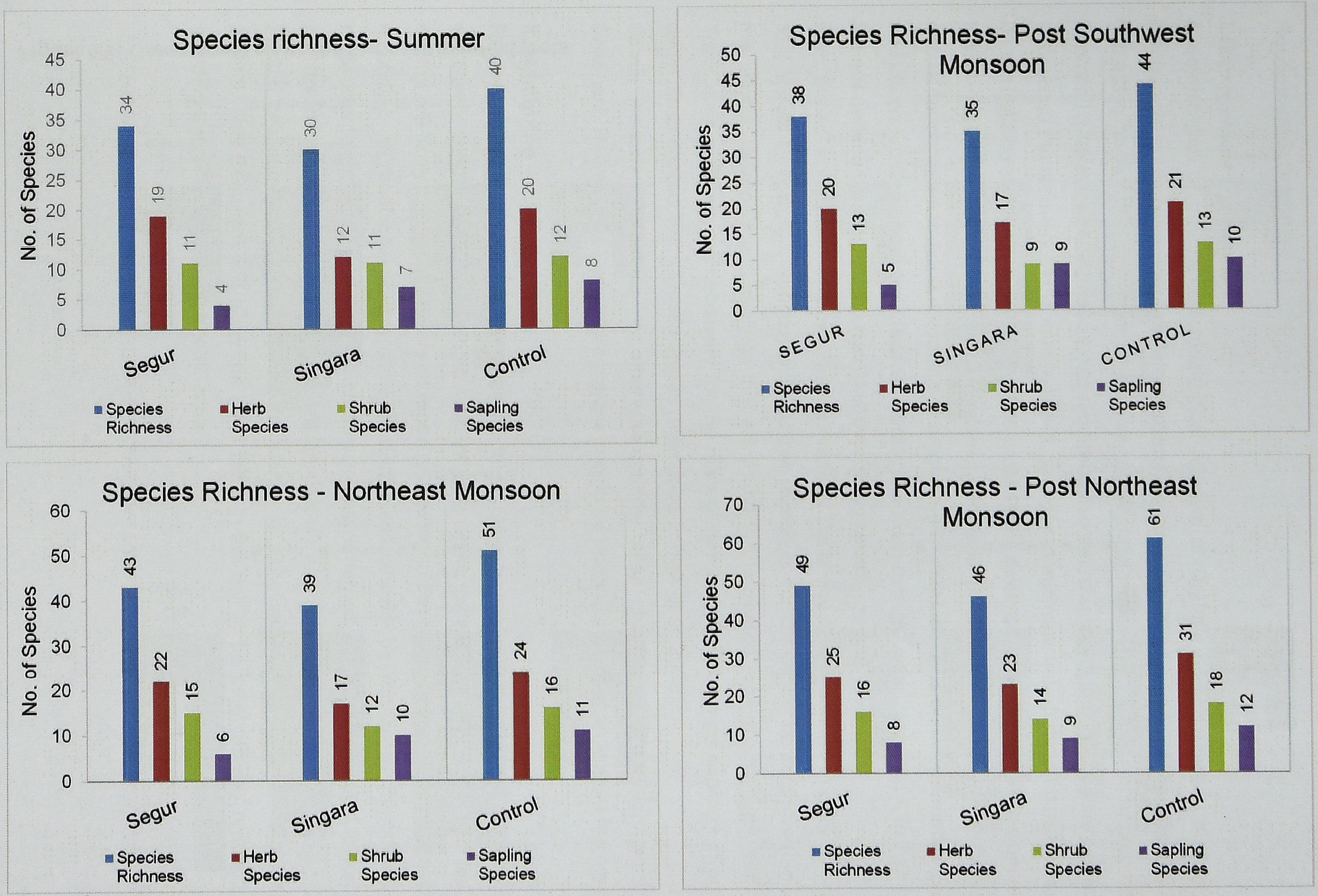


Figure 28: Species richness recored across seasons in Segur, Singara and control plots located in scrub habitat

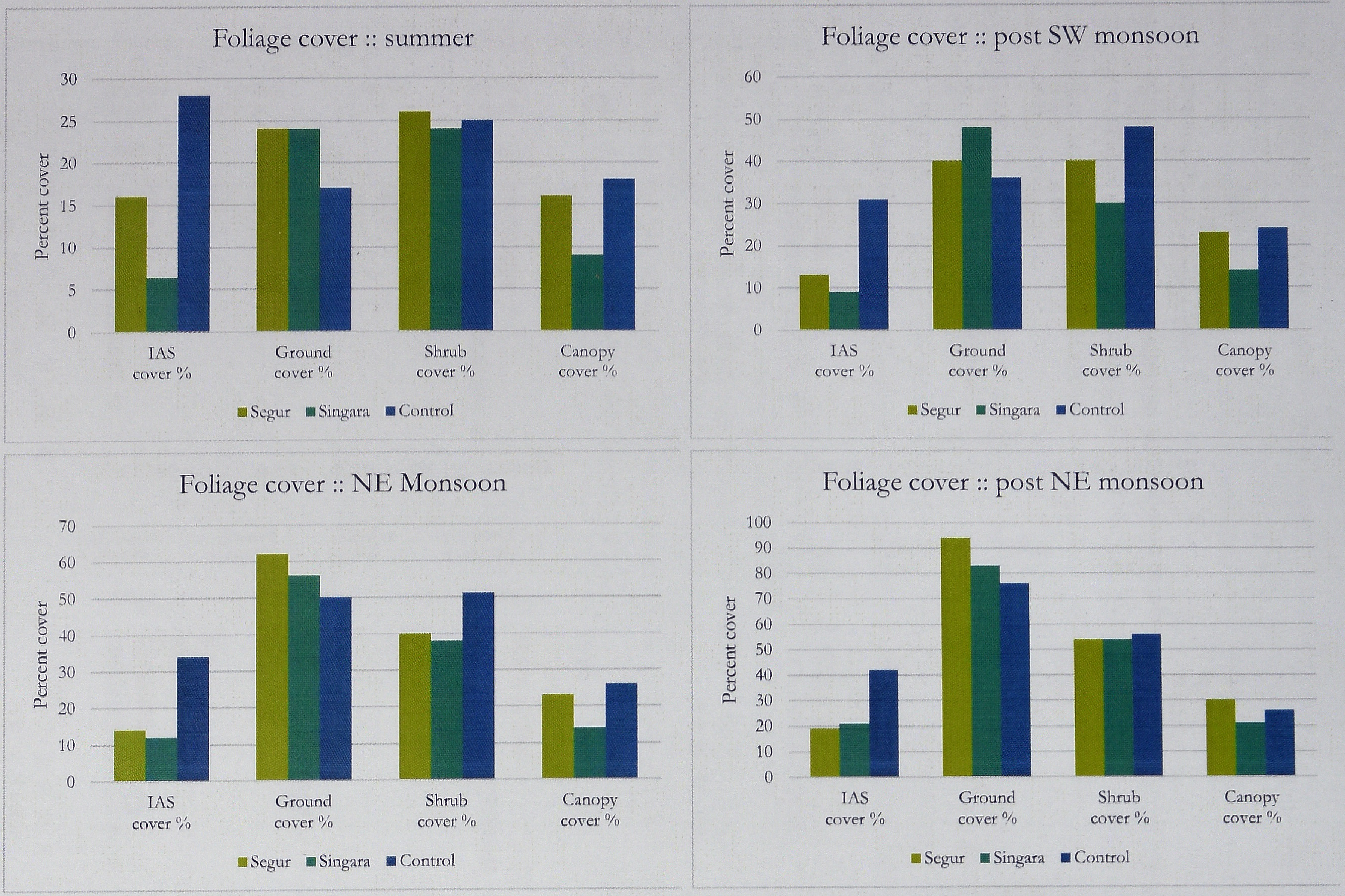


Figure 29: Green cover recorded from scrub forest plots

Recommendations

i. Management of *Opuntia*

A combination of manual and mechanical removal of *Opuntia* (Prickly Cactus) is proposed. Mechanical control can be considered optimal for removing large stands of *Opuntia* spp. as a first stage, avoiding contact with its long spines. Manual removal is considered appropriate for removing scattered, small stands that require active searching and highly selective removal to encourage the recovery of the invaded area. In order to minimise the effect of heavy machinery on the habitat, existing old paths should be used. In the second stage of removal, the remains of broken cladodes and stands hidden by dense vegetation that have been left in the first stage should be removed by hand. Grubbing or digging up Prickly Cactus is an effective management options on small, isolated populations. Cutting the main root of prickly pear 2 to 4 inches below the soil surface with a grubbing hoe or shovel is suggested.

Also, the soil compaction and disturbance made by the heavy machinery (in the plots with sandy soil) should be restored. Subsequently, further rounds of control should be carried out in which the shoots, resprouts and saplings that are found in the treated area are manually removed. Tools such as pliers are necessary for the manual removal of shoots and saplings in order to avoid direct contact with *Opuntia* spines (García-de-Lomas et al. 2018).

Small, isolated infestations on otherwise healthy sites should be given high priority for treatment. Perimeters of larger infestations should be treated first and then worked the center.

ii. Monitoring

Regardless of the approach followed, it must be recognized that prickly pear cannot be effectively controlled within a single year or by treating only one time. Acceptable levels of control will likely require 2–3 years of repeated management methods with followup treatments extending an additional 2–3 years. Treated areas should be monitored periodically and measures taken to control missed plants and newly emerged seedlings. It is also important to monitor the return of desirable native plant species.

Annual monitoring at an appropriate frequency is necessary to achieve effective ongoing control. This frequency will allow the seed bank in the soil to be progressively reduced, thus avoiding the reinvasion of the treated area.

Secondary Invasion

The interaction of a successful invader in an ecosystem leads to the emergence of a new species as invasive, it is called secondary invasion. In other words, secondary invasion happens if the already established IAS modifies the recipient ecosystem to the benefit of other exotics present (Green et.al. 2011). Properties of recipient ecosystems can be altered by the impacts of previously successful invaders, meaning that the presence and impact of those IAS should be considered a character of the ecosystem to which subsequent new invaders may respond (Green et.al. 2011). Successful invasive species may facilitate the invasion success of others either alone or as a community and the phenomenon is termed as “invasional meltdown” (Simberloff & Von Holle, 1999) through direct or indirect mechanisms. This kind of phenomenon may be very common given the ubiquitous presence of invasive species in almost all ecosystems and, as such, requires formalization within the broader framework describing the determinants of invasion success. Although there are no serious secondary invaders in the scrubland habitat, the deciduous forests and montane forests have many numbers of species that are potentially invasive.

Table 8. Target primary invasive plants

Scientific Name	Popular Synonym	English Name	Tamil Name
Opuntia vulgaris Mill.	*Opuntia monacantha* Haw	Prickly Cactus, Prickly Pear	Sappathi kalli
Lantana camara L.	*Lantana aculeata* L.	Tick berry, Big Sage	Jimmiki Poo, Unni chedi
Chromolaena odorata (L.) King & Robinson	*Eupatorium odoratum* L.	Siam weed, Goat weed	Pacchai
Acacia mearnsii Wilde	*Racosperma mearnsii* (De Wild.) Pedley	Black Wattle, Blackwood	Seegai, Chavukku
Parthenium hysterophorus L.	*Parthenium glomeratum* Rollins	False Ragweed, Carrotgrass	Mookutthipoo

Table 9: Secondary invasives found from the study area

S.No	Family	Species Name	Origin	Habitat		
				Scrubland	Deciduous	Evergreen
Primary Invasives						
1	Asteraceae	***Parthenium hysterophorus*** L.	Tropical America	✓	✓	
2	Cactaceae	***Opuntia vulgaris*** Mill.	Tropical America	✓		
3	Mimosaceae	***Acacia mearnsii*** Wilde	Australia			✓
4	Solanaceae	***Cestrum aurantiacum*** Lindl.	Tropical America			✓
5	Verbenaceae	***Lantana camara*** L.	Tropical America	✓	✓	
Secondary Invasives						
1	Asteraceae	***Ageratina adenophora*** (Spreng.) R.King & H.Robinson	Central America		✓	✓
2	Asteraceae	***Ageratum conyzoides*** L.	Tropical America		✓	✓
3	Asteraceae	***Bidens triplinervia*** H.B.K.	Tropical America		✓	
4	Asteraceae	***Lagascea mollis*** Cav.	Tropical America	✓	✓	
5	Asteraceae	***Synedrella nodiflora*** (L.) Gaertn.	Tropical America		✓	✓
6	Asteraceae	***Crassocephalum crepidioides*** (Benth.) S.Moore	Tropical Africa		✓	
7	Caesalpiniaceae	***Senna uniflora*** (Mill.) H.S. Irwin & Barneby	Tropical America	✓	✓	
8	Convolvulaceae	***Ipomoea parasitica*** (Kunth) G.Don	Tropical America		✓	
9	Crassulaceae	***Kalanchoe pinnata*** (Lam.) Pers.	Tropical America	✓	✓	
10	Euphorbiaceae	***Synadenium grantii*** Hook.f.	Africa	✓		
11	Fabaceae	***Aeschynomene americana*** L.	Tropical America		✓	
12	Lamiaceae	***Hyptis suaveolens*** (L.) Poit.	Tropical America	✓	✓	
13	Lamiaceae	***Salvia leucantha*** Cav.	Tropical America			✓
14	Rubiaceae	***Mitracarpus villosus*** (Sw.) DC.	Tropical America	✓		
15	Solanaceae	***Solanum mauritianum*** Scop.	Tropical America			✓

V. Key findings and Recommendations

1. Key Findings

The study has provided an insight into the manner in which the removal of the invasive species has been undertaken in Nilgiris landscape through various programmes. The following is a list of key findings from the study.

i. **Lack of holistic invasive species management plan**

It is evident that the IAS are being handled only as weeds, and thereby removed using only mechanical processes and tools. The focus should ideally be on eradication of the unnecessary species, rather than removal. Likewise, parameters such as soil quality, precipitation and wind patterns, seed dispersal by mammals, seedling recruitment rate and birds have not been factored into the programme.

ii. **Ineffective invasive species control and re-invasion**

The present invasive species removal process was observed to be largely unsuccessful which can be attributed to prolonged invader persistence and reinvasion as well as native propagule limitation.

Analyzing the overall efficiency of invasive species removal across habitats- the removal process seemed to be most effective in scrub habitat followed by montane habitat and the least in deciduous habitat.

That IAS have the added dimension of being prolific in their occurrence and spread, typified by robust, often dormant seed banks. This has not been factored into the physical removal process and also in financial outlay.

Re-invasion by primary invasive species and invasion by secondary invasive species were recorded in many plots where removal had been undertaken. Studies have shown that ecosystem restorations are particularly prone to invasion, as the restoration process results in disturbance and increased resource availability. Invasive plant control methods are known to enhance invasibility in many cases through resource release and decreased competition, resulting in reinvasion by the invasive plant targeted for control, or colonization by a novel invasive plant. Invasive plant control often leaves open niches for reinvasion or for novel invaders to colonize.

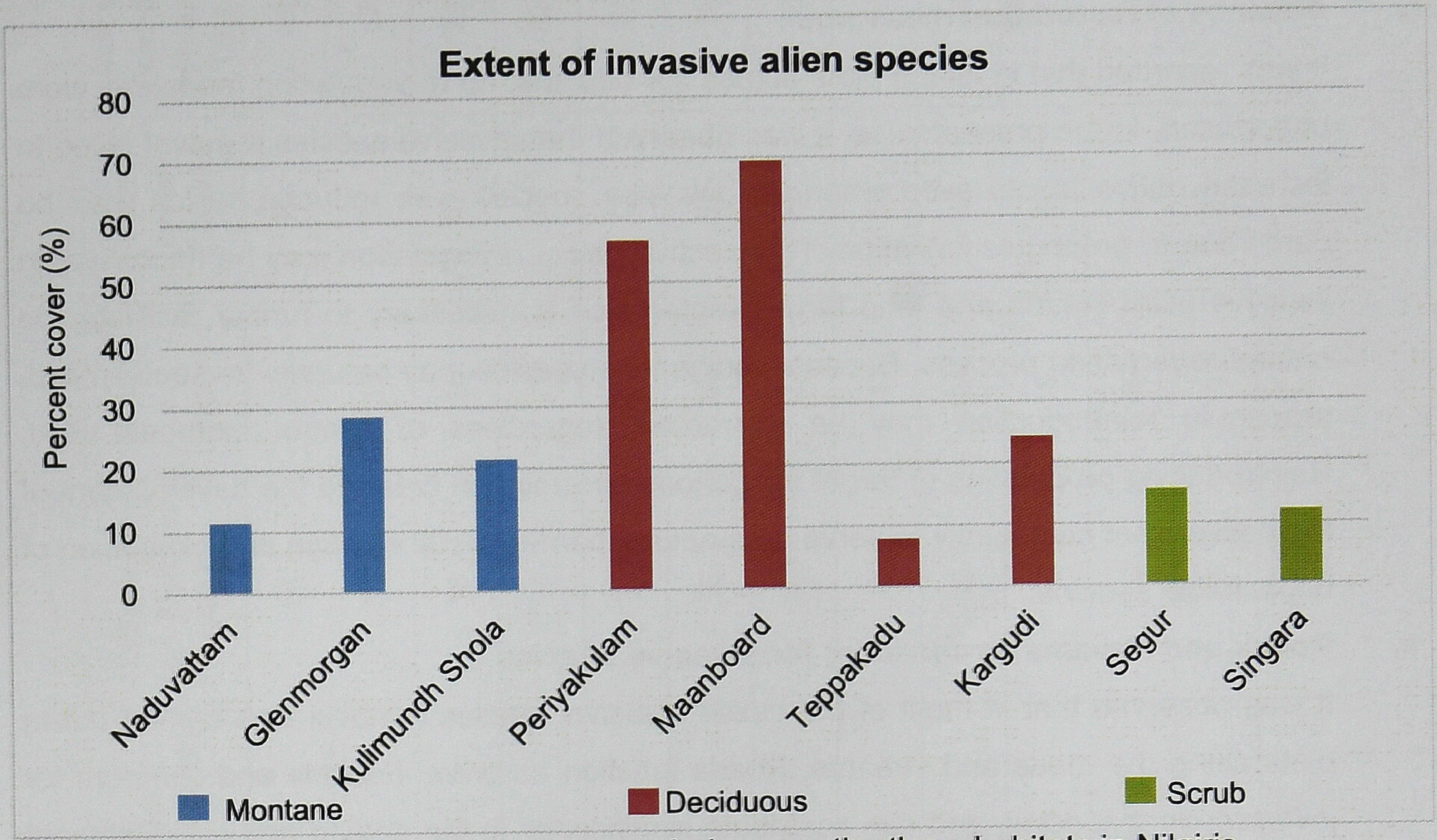


Figure 30: Percentage invasive cover recorded across the three habitats in Nilgiris

That there are other co-generic IAS of plants that would overtake the habitat post the removal of the target IAS has not been factored into the removal programme, which is indicative of the poor understanding of the ecology of the terrain under consideration.

iii. Absence of regular long-term management and monitoring

It was recorded that overall there was an absence of long time monitoring and management of the sites where invasive species had been removed, and was limited only to one to two years. In the case of deciduous forest habitat, maintenance was carried out for two years in Teppakadu and Kargudi, while it was done only for the first year in the case of Maanboard and Periyakulam. On the other hand, no maintenance was carried out in the case of scrub forest in Segur and Singara. In case of montane habitat, maintenance was carried out for two years in Naduvattam and Glenmorgan, while no maintenance was carried out in plots located in Kulimund shola.

Studies show that extensive long-term control programmes are most likely to positively impact native species regeneration. Long-term approaches that utilize multiple treatments and follow-ups (rather than single application strategies) are also more successful at reducing the target invader.

Reid et al. (2009) showed that long-term programmes result in a higher abundance of native plants than short-term programmes.

iv. Absence of restoration measures

It was recorded that in all the plots across the habitats, no re-vegetation measures were undertaken. In the present case, it was observed that invasive species removal failed to increase native plants even when the invasive species was reduced, which may be partly due to propagule limitation. Thus, active native revegetation may be necessary in invasive plant control and long term maintenance is necessary to further facililate the natural regernation process. Because indigenous species may naturally be seed-limited, propagule reintroduction may be warranted, regardless of control methods used. Reintroducing propagules of target indigenous species can catalyse the development of the native plant community to serve as a natural barrier to colonization and expansion of undesirable species.

v. Roads and streams as corridors for invasive species

It was observed that in most of the cases invasive species removal was carried out in plots along the roads and streams. Roads function as prime habitats and corridors for invasive plant species, and can contribute significantly to the spread and establishment of weeds inside protected areas. Both roads and streams act as corridors or agents for dispersal, provide suitable habitat, and contain reservoirs of propagules for future episodes of invasion. Roads facilitate invasion both by acting as corridor in a landscape and by creating or chanelling disturbance. Riparian corridors along streams may also serve as corridors for dispersal of plants including exotics. Disturbances along the roads and streams such as road traffic and flooding may also facilitate dispersal (via vehicle tyre and streamflow).

Table 10: yearwise comparision of the results from plots

Year of operation	Location	I year maintenance	II year maintenance	Average Sapling turnover (per year)	Species Richness (2017)	Indigenous spp. Richness (2017)	Canopy cover (2017)	Ground cover (2017)	Average invasive occupancy (2017)
2012 –13	Maanboard	yes	-	19.25	72	54	40	78	69
2012 – 13	Periyakulam	yes	-	48.25	73	58	15	56	57
2013 – 14	Pavermund	-	-	100	62	38	10	61	29
2013 – 14	Carriot Shola	-	-	42.25	68	54	26	73	12
2013 – 14	Kulimund	-	-	59	45	29	27	50	22
	Control-montane	-	-	53	70	56	26	59	28
2013 – 14	Mayilarapatti	-	-	17	60	50	23	55	16
2013 – 14	Aanaikaal	-	-	41	56	46	15	53	12
	Control-scrub	-	-	48	65	56	24	45	34
2014 – 15	Teppakadu	yes	yes	56	69	54	8	82	8
2014 – 15	Kargudi	yes	yes	33.5	89	70	37	64	24
	Control-deciduous	-	-	58.25	75	56	32	57	42

Spots of Endemicity

A species confined to and thriving in a geographical area of restricted size is termed as 'endemic' to the location. The presence of endemic species is an important metric in determining the conservation value of a landscape or habitat. Endemic species are threatened by the adverse anthropogenic pressure like habitat fragmentation and the encroachment of habitat by invasive alien species. The term applies to both fauna and flora.

The study also focused on spots of endemicity where the habitats of rare species are taken over by the bio-invasion. In our study area, Naduvattam region is observed to be a spot of endemicity, as it is far from human habitation and close to the Mukruthi National Park. The place is often visited by rare and highly endemic smaller carnivores (like Nilgiri Marten); also, the Shola plant species seem to have found refuge in this habitat. Pykara is also of similar habitat type, but is distanced from National Parks and in close proximity to Tea estates, human habitations and pine plantations. *Nothapodytes nimmoniana* (syn. *Mappia foetida*) and *Michelia nilgirica* are categorized as 'Vulnerable' in Tamil Nadu by IUCN Red List; these are found in the montane forests.

Area under the threat

It is important to know how much area has been subjected to bio-invasion by plant species. The ability of an exotic plant to invade into the forest community is vigorous and robust; and so, the estimation of area under invasive plants will always remain inaccurate. The data collected from the field staff is an approximation and this phenomenon of escalating bio-invasion needs to be understood by their science. Table 3 mentions the extent of infested area range-wise and the cost involved with it.

Restoration of indigenous species

The study recorded the presence, status, and diversity of indigenous species in every plot. This data was quantified for four surveys in the same field in two years. For consistent data and information about the presence and establishment of indigenous plant species in the region, and to understand about the replacement strategy by natural process, there needs to be a long-term monitoring procedure. Maintaining the affected area from further invasion and proper clearing of the upcoming exotic plants regularly by the forest managers will help in the recovery of native biodiversity. The above activity demands regular dedicated funds for the maintenance in the following years, which is a lacuna as of now. The tables (22-30) of quantitative data on plants recorded with column 'origin', describe the presence of indigenous species and other non-indigenous plants in the study sites.

Apart from HADP, EPRED (Environmental Protection and Renewable Energy Development Fund), Pilot and TBGP schemes, a state funded Fodder Scheme has been carried out in 2013-2014 in the Segur and Singara forest range of Nilgiris North division. With this, indigenous tree saplings and bamboo were planted and maintained closer to the area where the *Lantana* and *Opuntia* have been cleared. There is no specific allocation of funds for raising and maintenance of locale-specific saplings in the HADP operated area.

The area of operation has been decided by the experienced field staff, where the infestation is heavier. The shrub and lower canopy of scrub forests have been degraded to the extent that only mature trees withstood the invasion. Further, the soil is affected by the allelopathic effect of invasive plants delaying the establishment of indigenous seedlings. Therefore, along with tree saplings, the ground cover (especially grasses) as well shrub cover should also be improved to revitalize the soil and enhance natural regeneration to have a healthy forest and a resilient ecosystem.

Pioneer Species

Pioneer species that were observed in the habitats where IAS removal has been undertaken are as follows:

1. Bracken Fern

Pteridium aquilinum is the scientific name of Bracken Fern (Pteridophyte) belonging to family Dennstaedtiaceae. These large vascular plants are commonly found in the montane temperate grasslands at medium to higher altitudes of Nilgiris. They are the first species to colonise the landscape immediately after a fire; thus, they are considered as bio-indicators of occurrence of fire. This fern is of cosmopolitan presence and is locale specific (i.e., temperate climate and open land). These cannot be considered as invading plant community.

2. Raspberries

About nine species of Raspberries are recorded from Tamil Nadu that are pioneers in colonizing a landscape. *Rubus* is the generic name for this prickly-plant. They require more sunlight for thriving as thickets. *Rubus* are indigenous species found growing as habitat-specific in the medium to higher altitudes of Nilgiris. These thickets are not to be considered as exotic nor invasive.

3. Grasses

Many grasses (Poaceae members) are found to colonise as early as possible in the disturbed or cleared forests. Most of them are indigenous as seen in deciduous and scrub forest floors. They are also short-lived in vegetation phase during the lean season. *Chloris dolichostachya*, *Apluda* sp., *Eragrostis* spp., are some of the examples from deciduous forests.

4. Other plants

Sida cordifolia, Leucas urticaefolia, Leucas martinicensis, Achyranthes aspera, Orthosiphon thymiflorus are the pioneer plants observed in the drier parts of Nilgiris North forest division and Mudumalai Tiger Reserve post-monsoon. They are found in the drier habitats. The plants recorded are listed in the Tables from 22 to 27.

Faunal groups

Higher vertebrate fauna like herpetofauna, avifauna and mammals have been recorded in varying seasons and in all the landscapes. All-out-search method was carried out for studying the associated animal species (Annexure III). Avifauna (birds) was studied systematically for distribution and diversity in each permanent plot (Table 19). In view of the fact that bird taxonomy is well established, inventories were prepared for all the seasons. Totally, 122 bird species were recorded in the study; including two critically endangered (CR) vultures and two vulnerable (Vu) bird species. At the level of individual plots (Table 20), Sigur and Singara recorded the highest number of bird species, while Naduvattam has the lowest diversity. Thus, Scrub forests support high diversity of birds, when compared to wet montane forests.

Of all the faunal groups studied, it is interesting to note that the plots/area that were worked had the presence/sighting of mammals typical to the landscape, and more importantly, harboured 19 species of mammals (Table 21) that are protected under the Wildlife (Protection) Act, 1972.

2. Key Recommendations

In terms of programme implementation and the constraints therein of the current study, the following are the key recommendations:

i. There should be locale-specific techniques for the removal of IAS coupled with species-specific protocols. This will ensure the effort put in for the purpose to be fully utilised both in terms of man power and financial outlay. The outputs should be cost-effective.

ii. **After identifying the heavy growth of infestation for eradication, the approach for removal could ideally be started from the higher altitude in that specific affected region**. Although the task is much tougher, positive results could be obtained with this approach.

iii. **The maintenance fund for the ensuing years is very critical in the entire process of eradication**. The entire effort of the first year for removal would be rendered ineffective when there is no practice of deweeding in the subsequent years. Saplings (of wattle) and seedlings (*Lantana, Eupatorium*) flourish within short time to form dense growth.

iv. Research on invasive plants needs to be intensified through laboratory and field trials. The already established collaboration with external institutes could be strengthened and the outcomes be implemented. Herbaceous exotic plants need much more careful protocol for their obliteration.

v. Techniques experimented in other parts of the country could be tried for the removal practice provided it suits the habitat and landscape. *Lantana*, for instance, was removed using a specially made tool, where the root-stock alone is pulled upside more specifically. The experiment of 'cut root-stock' method for Lantana initiated in Corbett National Park has been successful also in Nagarahole and Bandipur national parks. Furthermore, attention should be given while exercising these techniques, a small error or negligence will give a chance for the target species to re-emerge; especially in the absence of maintenance funds.

vi. Likewise, for speedy removal of the cleared material (IAS), local specific, special provisions need to be evolved and utilized. In situ stocking of the removed plant material is counter productive to the removal operations.

vii. Doctrine of early detection and rapid response could be followed. Remote sensing could be a tool for identification and detection of the invading plants; but in the absence of high resolution data and expertise, it is difficult to differentiate native and non-native species owing to physical and biological heterogeneity. *Lantana* and *Chromolaena* peaks in vegetative growth after the Southwest Monsoon (September), whereas, the Parthenium peaks after Northeast Monsoon (January).

viii. A larger approach to address the above problem of managing the invasive species would be the use of advanced GIS (geographical information system) with the ground verification by frontline staff of the department. This method is complicated and there is a cost involved in procuring recent imageries of forests. After the mapping in meticulous scale, the areas have to be segregated for classifying in accordance with density and spread of the bio-invasion. The technique is referred to as Hyperspectral Remote Sensing.

ix. Prioritizing critical habitats that require management of invasive species and long-term monitoring and management scaled to timeframes of ecological processes is critical. Phased expansion of managed sites is essential, such that, over time, high-priority habitats can be isolated from dispersal regime originating from abutting invasive plant source populations.

x. Removing of the invasive species should be followed by uprooting of the seedlings in the following post-monsoon period; this should be practiced for at least for three consecutive years. Effectiveness could be observed in case of tree species like Wattle and Pine. Other things being the same, more regular monitoring and management efforts are likely to be more effective than a single-time effort.

xi. Ecological restoration of IAS-free zones and imparting higher protection towards the indigenous forest and plant communities that are still unaffected in select patches needs to be undertaken.

xii. Prevention of reinvasion and also secondary invasion by other exotic species should be given priority by the local forest managers. Locale-specific designs have to be developed based on research for this purpose.

xiii. There was apprehension that the forestry sector is migrating from focusing on the ecological values of natural habitats (as envisaged in Twelfth five-year plan of Tamilnadu) to a more targeted approach. It was also felt that concerted attention on undertaking research to improve methods for eradicating invasive alien plants in an efficient manner is essential rather than investing in huge man power and machinery.

xiv. The best spatial approach for control, level and length of effort required for invader control, and appropriate monitoring also need to be established.

xv. Given that some invasive plants are more aggressive than others, considerations such as their level of aggressiveness ease of controlling their spread, and potential costs are used in assessing appropriate course of actions.

xvi. The short-term nature of implementation and monitoring of invasive plant control is often due to logistical and financial constraints.We found that many studies had a limited control implementation time and / or monitoring response period. Assessment of control is compromised by short-term monitoring because long-term conclusions can differ from initial findings (Blossey 1999). Implementing control methods for short time periods can also complicate control method evaluation, as evaluating multi-year control efforts can reveal important outcomes.

xvii. Native revegetation should be better integrated into invasive plant control. Effective revegetation efforts offer the greatest control. Planting diverse species assemblages can capture resources and space quickly to limit the potential for undesirable species to colonize and persist. To capitalize on the use of native plant species to resist or constrain invasion, restoration practitioners will need guidance on how to select species or genotypes, planting densities, and revegetation methods to minimize invasive plant impacts. In this regard, planting, native grass varieties, tall bamboo saplings and other indigenous species have been found to effectively check the spread of *Lantana* (Junglescapes Charitable Trust, 2014)

xviii. Although invasive plant control research has improved management, our study highlights shortcomings that limit insight into the ultimate goal of ecosystem restoration. Linking research and restoration through adaptive management may address these limitations. Adaptive management involves partnerships of practitioners and scientists that assess treatment outcomes on a landscape scale, and increase knowledge of treatment effectiveness with models. Adaptive management naturally fosters cost effectiveness and practicality, and also improves understanding of stochastic influences on invasive plant management (e.g. the effect of annual climate variation on control outcomes). The focus therefore remains on the long-term objective of ecosystem restoration, rather than short-term changes, such as temporary decreases in invader abundance. Invasive plant control research could be well-served by this approach.

Guidelines for Evolving a Comprehensive Programme on IAS

Principles

Based on the results of the intensive assessment of the efficacy of the removal of Invasive Alien Species in the Nilgiris, and a consolidation of inputs obtained from brainstorming sessions and a review of secondary literature, the following points are being elucidated as guidelines for the management of Invasive Alien Species:

- Management of Invasive Alien Species needs to be entrenched in scientific principles, and to begin with the use of definitions needs to be streamlined. The most accepted and widely used definition of Invasive Alien Species is as follows: '.... is defined as the one showing the establishment of self-sustaining plant populations that are expanding within a natural plant community with which they had not previously been associated (Vitousek et al. 1995).
- Attention needs to be given to operationally define the terms used in the deliberations on IAS, such as intentional introduction, un-intentional introduction, bio control, removal, etc. A glossary of terms needs to be drafted and endorsed.
- It is also to be recognized that the international Conventions and commitments pertaining to the conservation of biological diversity for human well-being detail Invasive Alien Species as a priority. For instance, Target 9 of the Aichi Targets states the following; *"By 2020, invasive alien species and pathways are identified and prioritized,*

priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment." Hence, in pursuance with India's commitment to meet Aichi Target 9, CBD Article 8 (h) and the Biological Diversity Act, 2002 and Rules 2004, there is a need to devise a dedicated National Policy for IAS.

- As the National Policy is being deliberated upon, Tamil Nadu could take the lead and initiate the process by developing a state policy framework/guideline on IAS taking into consideration, regional, national and international provisions and protocols.
- In doing so, it is important to engage and consult with the major line departments, academia, civil society organisations and local communities in view the significant role of species introductions (deliberate/strategic/uninformed or accidental) played by humans for meeting their food and other allied needs.
- While the impact of IAS on natural systems is poorly understood, it is inevitable that certain components gain additional attention. It is hence important to take up a systematic effort to study the impact of IAS on terrestrial, aquatic and marine ecosystems of the state, for these systems are not mutually exclusive.
- It is also imperative that Tamil Nadu identifies a list of Invasive Alien Species, which could be termed as the Black List that need to be addressed on priority. The biology of each of the species needs to be detailed as part of the negative list so that appropriate species/habitat/landscape specific action could be taken. IAS fact sheets need to be developed as also maps of distribution. The list needs to be reviewed once in five years.
- Based on research carried out by credible institutions else-where in the country, a manual on options and techniques available to manage IAS needs to be developed and disseminated widely. Research on the ecology of IAS especially on seed setting and flowering in plants, breeding efficiency in fishes etc., is to be agreed upon as a priority research need. Other critical topics in this regard include the phenology of IAS, changes in species-community composition etc.
- IAS management and mitigation needs to be based on the established ecological theories such as ecological succession. The fundamental unit of planning could be at the scale of landscape, while management could be based on prioritization based on parameters of impact/intensity/criticality etc. Evidently, a singular approach would not suffice. Combination approach while being ideal needs to be measured against management and legal issues.
- The pathways of invasives need to be mapped to understand the connection with other sectors such as agriculture, horticulture, fisheries etc. The pathway would also help in enabling the Principle of Avoidance. Quarantine and phyto-sanitary provisions for plant

and animal species needs to be re-defined in the context of IAS and details of this need to be disseminated widely.

- The economics of IAS *vis a vis* the possibility of conversion into income generating activities for local communities, as also being a substitute for intensively used native species needs to be reviewed, and appropriate interventions be developed.
- There is a need to evolve a concerted, inclusive approach to manage and address IAS. The existing body of knowledge has to be capitalized upon as the first step towards the management and mitigation of IAS. In this regard, the existing forest policies need to be reoriented / modified taking into consideration the threat of IAS.
- Mechanisms and metrics to assess and monitor the impact of IAS need to be evolved taking into consideration ecological, hydrological, social and economic dimensions. A Tool Kit on Forest Invasive Species could be developed on a priority basis.
- Management of IAS needs to be on a three-pronged strategy of coordinated research, action and management. It should be a cross cutting agenda of all the line departments and sectors of the state, to ensure that the agenda, mandate and action of the departments do not offset each other.
- A dedicated strategy to involve the larger community – notably media, farmers, local communities, academics, professionals, corporate sector etc. on issues pertaining to IAS and its management needs to be evolved and implemented. Events such as 'Eradication Week' need to be organized. This strategy should accord importance to building capacities across sectors / stakeholders on the fundamentals and management of IAS.

Impact of invasive species on forests

An integral part of sustainable forest management is measures to protect forests from natural threats such as fire, insects and diseases. Increasingly, an additional and more severe threat has been affecting the forest sector worldwide - invasive species. Invasive species are any species that are non-native to a particular ecosystem and whose introduction and spread causes, or are likely to cause, socio-cultural, economic or environmental harm or harm to human health. There is a considerable concern in the forest sector since many of the tree species used for agroforestry, commercial forestry and desertification control are alien or non-native to the area (http://www.fao.org/forestry/aliens/en/). The damages and impacts of non-native plants on forests have not been completely determined, but the following are generally recognized. Non-native invasive plants:

- Limit or stop productive land management and regeneration of forests and grasslands.
- Displace and permanently decrease biodiversity and wildlife habitat.

- Alter vital ecological processes such as soil formation, watershed function, and pollination of native plants.
- Present extreme fire hazards to forests.
- Harbor plant and animal diseases.
- Limit land access for recreation such as hiking and bird watching (Miller et al. 2013).

Guidelines for invasive species removal

Thematic areas

I. Background

- Planning and decision-making- Establish strategic, prioritised programmes for the prevention and management of invasive species.
- Raise awareness of the impacts of invasive species on biodiversity, human health, livelihoods and society, and generate support, including funding, for action to manage and reduce them.
- Develop the skills, infrastructure, technical support, information management, networks and linkages required to manage invasive species effectively.
- Ensure that appropriate legislation, policies, regulations and procedures are in place, operating and complied with, to underpin the effective prevention and management of invasive species.

II. Information and prioritisation

- Baseline and monitoring change- Establish baseline information on the status and distribution of invasive species, and programmes for detecting and predicting change, including range changes and emerging impacts.
- Prioritisation- Establish and implement effective systems for assessing risk and prioritising invasive species, pathways and sites for management.
- Research on priorities- Understand priority invasives, including their biology and impacts, and develop effective management techniques.
- Build the Capacity to Increase Understanding of and Treatments for Invasive species- Identifying research needs to manage current and future threats of invasive species is challenging because of the complexity of interactions among biotic and abiotic factors. Different aspects of the invasion process (e.g., introduction, establishment, and spread) require different research needs, innovative concepts, and new tools.

III. Management action

- Biosecurity: Prevent the spread of invasive species across borders.
- Management of established invasives- Reduce or eliminate the impacts of established invasive species, by eradication, biological control, containment, exclusion, physical control, or impact mitigation.
- Post-management restoration- Restore and maintain native biodiversity, ecosystems, ecosystem services and other values, following invasive species management (IUCN, 2018).
- Expand Early Detection and Active Management Efforts- Early detection methods and prompt eradication efforts are needed once the invasive species is introduced. Management costs rise significantly once an invasive species becomes established and begins to spread. Thus, more research is needed to develop effective prediction, prevention, and early detection methods (Moser et al. 2009).

Strategy for removal of invasives

The spread and occupation of an invasive plant can be stopped only through regional and State plans and programs that are effectively implemented at the local level.

i. **Mapping and survey of infested areas-** It is important to map and define zones of invasion severity and show areas where different strategies should be employed. An invasive plant survey should be completed prior to the commencement of any landdisturbing activities to identify potential problem areas. Sites with invasive plants identified on them should be made note of in order to alter practices to limit their spread (e.g. control prior to land disturbance, cleaning of equipment and materials before leaving the site). As the pre-activity invasive plant survey acts as a base-line for potential infestations, a follow-up survey should also be undertaken to assess the invasive plant spread as a result of the pre-activities.

ii. **Managing Outlier Areas-** Outlier (or satellite) infestations exist beyond highly infested areas due to long distance movement of plants or plant reproductive parts. Outlier infestations must be detected and eradicated early if containment is to be successful. Early detection rests with education as well as organized search and surveillance efforts and strong reporting networks. Movement of contaminated equipment and materials must be effectively prevented to stop new outlier infestations from being established.

iii. **Managing the Advancing Front of Invasive Infestations-** All infestations along the advancing front must be found, mapped, and documented through intensive search and surveillance programs. The search and surveillance programs must include all ownerships including forests, plantations and agro-forestry areas. To stop seed dispersal from worsening the situation, treatments must be timely and persistent. For all work near or inside infested areas, extra care must be taken to ensure sanitation of equipment and personnel to prevent spread. Special habitats of rare plants and animals within the advancing front zone should be carefully treated to save from ultimate loss. The front must be held and then pushed back.

iv. **Managing Severely Infested Areas-** Surveys employing sampling techniques are required to quantify the acres of infestation. Concerted programs are needed to fully implement, support, and maintain management programs in severely infested zones. Equipment and personnel sanitation as well as quarantines of product movement out of severely infested areas must be strictly regulated to prevent both short- and long-distance movement of plants and reproductive parts. Any forest and nursery product movement must be monitored for contamination. Special habitats of rare plants and animals must be safeguarded from destruction and restored using special techniques. People's homes must be safeguarded against wildfire by highly flammable invasive plants.

Site-specific plan

Considerations in Developing a Site-Specific Plan

- What Is the Long-Term Plan for the Site? Control methods can change dramatically based on the site's planned uses. For example, if the long-term plan is to keep the site cleared of all tall vegetation, then a less selective and less expensive approach can be used. If one needs to protect indefinitely, a site that contains many desirable or rare species, then a more selective long-term treatment and monitoring plan needs to be considered.
- What Is the Need for Selectivity? Selectivity means targeting invasive plants while minimizing damage to neighboring native plants. One can control specific plant species with a selective removal, or one can completely clear the area of plants. In some cases, the native soil seed bank will reestablish itself.
- What Is the Intensity of Infestation? The intensity of infestation is determined by the relative area and height of occupation, the infestation's age, the size and growth form of the invasive species, and the longevity of the invasive species' viable seeds or other propagules in the soil. These factors can dramatically affect the methods, timing,

persistence, and costs of control and site rehabilitation. For example, one will need to spend considerable time and effort treating an invasive multi-stemmed tree that has grown at high infestation levels, has grown on the site for a decade or more, and has long-lived residual seeds. One will need less time and effort for scattered low-growing annual invaders with few residual seeds.

- How Does Timing Affect Control Methods? Understanding the life cycle of invasive plants helps the forest staff select the optimum time for applying control treatments as well as revegetation actions. If one knows the annual cycle of growth initiation, flowering and fruiting, drought responses, and periods of dormancy, one can plan the most effective approach. By cutting or uprooting at the appropriate stage in a plant's seasonal cycle, one can increase effectiveness and selectivity as well as reduce the need for additional retreatments. Other timing issues concern availability of labor and contract applications, number of treatments necessary in a season, and access periods for wetlands, high-elevation sites, etc.
- What Type of Labour Will Work on the Site? In-house, contract, and volunteer labor all have different strengths and distinct disadvantages. In some cases, volunteers use only manual or mechanical control methods suitable for small infestations. In-house and contract workers often are the best trained in knowing how to handle larger infestations that require special equipment, and other approaches.
- The cost of a project is directly related to treatment method, intensity of infestation, plants and areas that need safeguarding, and availability of resources. Once a plan is formulated, careful estimates of the costs must be made in light of realistic objectives. Once a plan is acted upon, it should be understood that disruption in scheduled treatments can cause major setbacks and even loss of the prior work.

Programme on management of invasives in forests

1. Planning

A plan should be made with proper schedule, resources required, and timeline for implementation. Both a short and long term plan should be made to include both specific infestation treatment regimes and options to integrate them into a general land management plan. Maps of infestation locations and priority ratings of invasive species assist in the planning process. An eradication and rehabilitation program for specific invasive plant infestations usually requires several years of treatments and many years of surveillance to check for rhizome and root resprouts, seed germination, or new invaders. Newer infestations and smaller plants require much less time than extensive and dense infestations. During the treatment and retreatment phase, one must take steps to safeguard, promote, or establish desirable vegetation. To effectively combat plant invasions and restore lands, one needs to carefully plan for each step in the program by incorporating primary and contingency schedules of action. One should project a minimum of 4 years and up to 10 years for older infestations and when less than maximum effective treatments are used. One can use short-term plans to target specific areas, but one will need a long-term management plan for an increasingly invaded landscape. One must consider surrounding lands, particularly the degree of current infestation in those lands as well as the invasive plant management programs in place.

2. Prevent entry and spread

- It is important to educate the staff and surrounding land owners about the invasive plants that pose major threats and how to prevent their entry.
- It is also important to learn to identify invasive species in the area.
- When possible, one should avoid driving vehicles, mowers, or equipment through infestations in seed or fruit.
- All seeds and debris should be brushed and wiped from clothes, boots, socks, and personal protective equipment. The undercarriage, radiator front, and engine compartments must be inspected and washed when suspected contaminates are present. Remove excess grease and oil that trap and carry seeds, fruits, and spores.
- When working in invasive plant infestations, the motorized equipment, especially the undercarriage and tyre surfaces, where seed and plant parts are often inadvertently caught and transported should be thoroughly cleaned.
- When moving cut invasive plants that have fruits and seeds offsite such, always cover loads or bag before transport.

- One should be careful not to disturb areas where there is a high probability of invasion. Most land disturbing activities raise the potential for establishment of aggressive plant invaders, especially when the invaders occur nearby. Most likely points of entry that need high-priority search and surveillance are: Lands adjacent to, highways, roads, and utility rights-of-way and their edges, especially after new construction or maintenance activities Internal roads, trails, and fire lines; lands next to streams, rivers, and wetlands, especially after recent flooding or high-flow periods; Harvested, thinned, burned, or storm-damaged areas during the years following disturbance.

3. Mapping and monitoring.

- Identify invasive plant location sites at risk, and denote treatments and their outcomes. One must identify those invasive plants that are present and those with potential to enter from adjacent lands, determine their locations and abundance, and record this information on a Geographic Information System (GIS) map.
- Make the locations easy to find again by marking them with using stone slabs and recording GPS coordinates for the location.
- Monitor the locations through repeated visits and record progress or the lack of it. Forest Department have to map as much area as possible with the funding available, before investing in unorganized treatments of extensive invasions, while new entries of severe invasives should be tackled early.
- The use of four option - Search, Survey, Inventory, Monitor, and Surveillance method, hereafter referred to as SSIMS, helps map, monitor, and track treatments with their results at several scales.
    1. Search- Start by looking at the most likely points of entry, like along roads and especially near bridges, and record any occurrence of invasive plants in such areas. Then expand the search as time and resources permit.
    2. Survey- Surveys can be used to sample large areas where search procedures have found numerous infestations that are too many to inventory individually. Surveys are also used to examine large tracks when the amount of invasion is unknown and access is difficult. By systematically locating plots or by band sampling across the landscape, one can record cover or number of clumps to determine the extent of occupation and acres covered. By mapping the survey plot findings, areas of highest infestation density and multiple invasive species can be identified.

iii. Monitoring- Inventories are used to record the location and area of every infestation and the treatments applied. Inventories can map individual patches and plants or circle them as a group when they occur in close proximity to one another. The GPS locations can be taken and mapped, or a sketch map made to plan the program of treatment and restoration. Monitoring requires revisits to inventoried points at scheduled times or resurveying tracks with scattered infestation to record and track treatment effectiveness and any further invasions.

iv. Surveillance- Everyone should be alert for new infestations and know how to report these when and where sighted.

- Eradicate, control or contain, and monitor results- One can eradicate an infestation by eliminating every invasive plant and its seeds in the infestation, a difficult task that requires timely and repeated use of the most effective treatments. One can control or suppress an infestation through medium effective treatments that mostly kill aboveground plant parts but that leave, even with repeated treatments, the live roots or rhizomes unharmed. One can contain an infestation by confining and restricting its spread through effective treatments that eliminate outlier plants, spots, or advancing fronts. Containment is often the only option when infestations continue to encroach from adjoining untreated lands. All treatments should be monitored for determining follow-up actions.
- Rehabilitate, restore, or reclaim treated lands with resistant and resilient native or noninvasive plants. Critical to rehabilitating a site is promoting or planting desirable species that are as aggressive as the invasive species. Effective treatment schemes for rehabilitation use an integrated approach that combines treatments in an appropriate sequence and at crucial times.
- Awareness- Communication between various stakeholder and and Government agencies is beneficial to transfer information promoting regional awareness. Information such as the invasive plant history of certain locations or invasive plant infestation locations may be beneficial to all parties. Invasive plant education and awareness programs developed co-operatively or individually by companies and agencies are essential in order to put the above preventive measures into practice (Srivastava and Singh, 2009).

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Annexure I Details of the target invasive alien species

Details of the target invasive alien species in the study (information sourced from Invasive Species Specialist Group, IUCN)

Chromolaena odorata (L.) King & Robinson (Asteraceae)

Habit: Tall herb

Origin: Tropical America

Common Names: Goat weed, Siam weed

Chromolaena odorata is a fast-growing perennial shrub, native to South America and Central America. It has been introduced into the tropical regions of Asia, Africa and the Pacific, where it is an invasive weed. It forms dense stands that prevent the establishment of other plant species. It is an aggressive competitor and may have allelopathic effects. It is also a nuisance weed in agricultural land and commercial plantations.

Habitat Description

The plant grows on a wide range of soils and grows in a range of vegetation types, e.g. forests (annual rainfall 1500mm), grassland (annual rainfall less than 500mm). For good growth of Siam weed seedlings, the relative humidity should be in the range of 60 – 70%; at values higher than 80% the growth performance was poor. Experiments show that Siam weed seedlings grew well at 30°C and even better on mulched soils at 25°C. In heavy shade, Siam weed will not seed. It has a negative relationship with tree canopy cover and appears to be most abundant on the edge of forested areas. It takes advantage of the flush of soil that becomes available after a disturbance, such as fire or land clearing for agriculture, and exhibits relatively high foliar N, P and K contents.

Reproduction

While the plant is capable of coppicing from older root stock or root crown, it has not been observed to propagate vegetatively. It has the capability to resprout from fire incident or removal (slashing activity). Life span of a seed under or over the soil surface is five years. Plants can germinate and set seed within a 12-month period.

General Impacts: This herb forms dense stands preventing establishment of other species, both due to competition and allelopathic effects. When dry, *C. odorata* becomes a fuel which may promote wild bushfires. *C. odorata* may also cause skin complaints and asthma in allergyprone people. It is a major weed in plantations and croplands, including plantations of rubber, oil palm, forestry and coffee plants.

Weed Management

Physical: Manual slashing and use of bush-cutter or tractor-drawn implements (bulldozing) are commonly used methods of control. Slashing causes regeneration unless followed by other control methods. Manual weeding is labour intensive. The use of bulldozing equipment is limited to areas that are accessible.

Biological: The biological control agent *Pareuchaetes pseudoinsulata*, where it effectively defoliates pure stands. It is less successful in scattered plants and patches. Another species, the stem gall fly *Cecidochares connexa* is a suitable biological control agent for *C. odorata*. At higher altitude sites (over 600 m) or where cloudy conditions, cold temperatures or long dry seasons limit the number and activity of flies control is slower and less adequate. Plants die-back and death especially in low altitude sites less than 300 m.

Opuntia vulgaris Mill. (Cactaceae)

Habit: Prickly shrub

Nativity: Argentina

Habitat Description

Opuntia species are found in drier region and open scrub forests.

Reproduction

With hardly any herbivore as competitor for this plant, the vegetative growth is prolific. The prickly pear is easily propagated and the tiniest bit of leaf will take root almost anywhere. Flowers bloom from March to May and have a magenta colour. The stem is because they are so succulent, they remain capable of rooting for several months after being detached from the parent plant. They can be moved in floods leading to infestations along river banks.

Weed Management

Biological: Mealy bug naturally decimated the Cactus population in the Mudumalai landscape, a decade ago. Cochineal (*Dactylopius* spp.) and Cactoblasts (*Cactoblastis* spp.) are the two most important biological control agents for prickly pear cacti. The two attack the cactus in a totally different manner. Cochineal species attach to the outside of the plant and sucks the moisture out of the plant. Cactoblasts are black and yellow striped grubs that tunnel into and devour the inside of the plant. Because of its oligophagous feeding habits Cactoblastis has been successful against a whole range of *Opuntia* species including 11 species. Dactylopius ceylonicus and Dactylopius opuntiae were used as biological control agents in *Opuntia vulgaris*.

Acacia mearnsii De Wild. (Mimosaceae)

Habit: Tree

Origin: Southeast Australia

There are multiple uses for this wattle. The tannin compounds extracted from the bark of wattle are commonly used in the production of soft leather. A range of other products, such as resins, thinners and adhesives, can also be made from bark extracts. The timber is used for building materials, the charcoal is used for fuel and the pulp and wood chips are used to produce paper. Wattle has some known medical applications, such as its use as a styptic or astringent. The agroforestry industry promotes the use of *Acacia mearnsii*, the planting of wattles has also been used as a soil stabiliser to decrease erosion.

Habitat Description

Grows in disturbed, mesic habitats (at an altitude of between 1000 – 2100 m asl) in the Nilgiris. Grows in a range of climates, including warm temperate dry climates and moist tropical climates. Wattle is reported to tolerate higher annual precipitation of between 670 – 2300 mm, an annual mean temperature of 14.7 – 27.8°C, and a pH of 5.0 – 7.2. *Acacia mearnsii* does not grow well on very dry or poor soils.

Reproduction

Acacia mearnsii produces copious numbers of small seeds that are not dispersed actively. The species may resprout from basal shoots following a fire. It also generates numerous suckers that result in monotypic thickets. Seeds may remain viable for up to 50 years.

General Impacts & management

The invasiveness of this species is partly due to its ability to produce large amounts of long-lived seeds and the development of a large crown (which shades other vegetation). Its leaves and branches may have allelopathic properties. *Acacia mearnsii* competes with, and replaces, indigenous vegetation. It may replace grass communities, reducing the carrying capacity of the land. By causing an increase in the height and biomass of vegetation the wattle infestations increase rainfall interception and transpiration, which causes a decrease in streamflow.

Mechanical: machineries can be used for removing the saplings and trees; manual uprooting of seedlings is highly labour intensive. Anecdotes indicate that wattle is sensitive to basal bark treatment with diesel alone and to girdling (stripping the bark). Girdling is a technique used to arrest the seed setting from mature trees, by killing the tree.

Lantana camara L. (Verbenaceae)

Habit: shrub
Origin: Tropical America

Uses

Lantana camara is a highly variable species. The stems of lantana, if treated by the sulphate process, can be used to produce pulp for paper suitable for writing and printing. However, it is hard to harvest, so is likely to be uneconomical. The roots of lantana contain a substance that may possibly be used for rubber manufacture. Apart from benefiting some bird species, *Lantana* is a major nectar source for many species of butterflies and moths.

Habitat Description

The diverse and broad geographic distribution of lantana is a reflection of its wide ecological tolerances. It occurs in diverse habitats and on a variety of soil types. It generally grows best in open unshaded situations such as wastelands, rainforest edges, and forests recovering from fire or logging. Disturbed areas, railway tracks and canals are also favourable for the species. *Lantana* does not invade intact rainforests, but is found on its margins (edge effect). *Lantana* benefits from the destructive foraging activities of introduced vertebrates and cattle. The prickly shrub grows under a wide range of climatic conditions; it does not appear to have an upper temperature or rainfall limit and is often found in tropical areas receiving up to 2000 mm of rainfall per year, provided that soils are sufficiently well drained. *Lantana* seldom occurs where temperatures frequently fall below 5°C. The plant is susceptible to frosts and low temperatures, and also shows low tolerance to saline soils.

Reproduction

The plant flowers in most places all year round if adequate moisture and light are available with flowering peaking during the wet summer months. Plants can flower as early as the second growing season. Initially, Lepidopteran species were thought to be the primary pollinators of lantana. Some butterfly species visit certain *Lantana* taxa more frequently than others due to differences in corolla length, inflorescence diameter and number of flowers per inflorescence. Thrips are present all year round, and are more efficient pollinators. Sunbirds are believed to play a minor role in pollination. Seeds are widely dispersed, predominantly by birds, but also by cattle and wild herbivores. *Lantana* seeds need high light conditions for germination and early growth and seedlings are unlikely to survive beneath parent bushes. Seeds germinate at any time of the year given sufficient soil moisture.

General Impacts: *Lantana* is now a major weed in many regions of the Palaeotropics where it invades natural and agricultural ecosystems. The plants can grow individually in clumps or as dense thickets, crowding out more desirable species. In disturbed native forests, it can become the dominant understorey species, disrupting succession and decreasing biodiversity. Its allelopathic qualities can reduce vigour of plant species nearby and reduced productivity in orchards. *Lantana* can greatly alter fire regimes in natural systems. The management of this species in fire susceptible ecosystems (scrub forests in eastern Nilgiris) should include targeted physical removal to reduce fuel loads. This could potentially increase the amount of run-off and the subsequent risk of soil erosion in areas infested with lantana. Lantana has been implicated in the poisoning of a number of animals including cattle, buffalo, sheep and goats. Poisoning mainly occurs in newly introduced young animals without access to other fodder.

Management

Mechanical: Mechanical clearing and hand pulling are suitable for small areas. Removing the rootstock with minimal impact on soil, could be a better way to mitigate the further spread of this species. Specialised tools for this purpose have to be prepared.

Biological: Biocontrol agents have decreased the volume of individual plants making other control methods considerably easier. None of the over 40 agents underwent trials have resulted in total control but some have been partially successful including *Teleonemia scrupulosa* (Hemiptera), *Octotoma scabripennis* (Coleoptera), *Uroplata girardi* (Coleoptera) and *Ophiomyia lantanae* (Froggatt).

Fungi have been used for against invasive weeds, the mycobiota of *L. camara* selected several fungal pathogens as potential biological control agents including *Prospodium tuberculatum, Puccinia lantanae* and *Ceratobasidium lantanae-camarae*.

Table 11: List of common alien/ invasive taxa reported from Nilgiris and Dindigul

S.No	Family	Species Name	Country / region of origin
1	Poaceae	***Avena sterilis*** L. var. ***ludoviciana*** (Durieu) Gill & Magne	Eurasia
2	Compositae	***Bidens triplinervia*** H.B.K. var. ***macrantha*** (Wedd.) Sherff	South America
3	Poaceae	***Brachypodium sylvaticum*** (Huds.)	Eurasia
4	Compositae	***Bracteantha bracteata*** (Vent.) Andr.	Australia
5	Poaceae	***Briza maxima*** L.	Naturalized, Native of Mediterranean
6	Poaceae	***Briza media*** L.	Naturalized, Native of Mediterranean
7	Poaceae	***Briza minor*** L.	Naturalized, Native of Mediterranean
8	Poaceae	***Bromus arvensis*** L.	Naturalized, Native of Tropical America
9	Poaceae	***Bromus catharticus*** Vahl	Naturalized, Native of Tropical America
10	Poaceae	***Bromus diandrus*** Roth	Naturalized, Native of Tropical America
11	Poaceae	***Bromus ramosus*** Huds.	Naturalized, Native of Mediterranean
12	Brassicaceae	***Capsella bursa-pastoris*** (L.) Medicus	Europe
13	Caryophyllaceae	***Cerastium glomeratum*** Thuill.	Mediterranean Region
14	Chenopodiaceae	***Chenopodium pumilo*** R.Br.	Tropical America
15	Cobaeaceae	***Cobaea scandens*** Cav.	Tropical America
16	Fabaceae	***Cytisus canariensis*** Steud.	Mediterranean Region
17	Fabaceae	***Cytisus hirsutus*** L.	Mediterranean Region
18	Fabaceae	***Cytisus monspessulanus*** L.	Mediterranean Region
19	Fabaceae	***Cytisus multiflorus*** Sweet	Mediterranean Region
20	Fabaceae	***Cytisus proliferus*** L.	Mediterranean Region
21	Fabaceae	***Cytisus scoparius*** (L.) Link	Mediterranean Region
22	Fabaceae	***Cytisus supinus*** L.	Mediterranean Region
23	Poaceae	***Eragrostis kiwuelsis*** Jedwabn.	Naturalized, Native of Africa
24	Poaceae	***Eragrostis tef*** (Zucc.) Trotter	Naturalized, Native of Africa
25	Compositae	***Erigeron karvinskianus*** DC.	Tropical America
26	Geraniaceae	***Erodium moschatum*** (L.) L' Herit	Europe
27	Euphorbiaceae	***Euphorbia helioscopia*** L.	Eurasia
28	Compositae	***Hypochoeris glabra*** L.	Europe
29	Compositae	***Hypochoeris radicata*** L.	Europe
30	Labiatae	***Leonurus sibiricus*** L.	Naturalized, Native of Eurasia
31	Solanaceae	***Lycium barbatum*** L.	South East Europe to China

S.No	Family	Species Name	Country / region of origin
32	Poaceae	***Pennisetum villosum*** R. Br. ex Fresen	Africa
33	Poaceae	***Phalaris aquatica*** L.	Australia
34	Poaceae	***Phalaris arundinacea*** L.	North Temperate Region
35	Poaceae	***Phalaris minor*** Retz.	Mediterranean
36	Plantaginaceae	***Plantago exigua*** Juss.ex Murr.	Eurasia
37	Plantaginaceae	***Plantago lanceolata*** L.	Eurasia
38	Plantaginaceae	***Plantago ovata*** Forssk.	Eurasia
39	Resedaceae	***Reseda alba*** L.	Eurasia
40	Resedaceae	***Reseda luteola*** L.	Eurasia
41	Polygonaceae	***Rumex acetosella*** L.	Mediterranean Region
42	Polygonaceae	***Rumex crispus*** L.	Naturalized, Native of Mediterranean Region
43	Compositae	***Senecio vulgaris*** L.	Naturalized, Native of North Temperate Region
44	Pedaliaceae	***Sesamum radiatum*** Schumach. & Thonn.	Africa
45	Compositae	***Silybum marianum*** (L.) Gaertn.	Tropical America
46	Solanaceae	***Solanum barbisetum*** Nees	Naturalized, Native of Tropical America
47	Solanaceae	***Solanum capsicastrum*** Link & Schau.	Tropical America
48	Solanaceae	***Solanum capsicoides*** Mart.	Tropical America
49	Solanaceae	***Solanum pseudo-capsicum*** L.	Tropical America
50	Rubiaceae	***Spermacoce latifolia*** Aubl.	Tropical America
51	Caryophyllaceae	***Stellaria monosperma*** Buch. - Ham. ex D. Don	Mediterranean Region
52	Caryophyllaceae	***Stellaria vestita*** Kurz	Mediterranean Region
53	Fabaceae	***Trifolium cernuum*** Brot.	Mediterranean Region
54	Fabaceae	***Trifolium dubium*** Sibth.	Mediterranean Region
55	Fabaceae	***Trifolium incarnatum*** L.	Mediterranean Region
56	Fabaceae	***Trifolium pratense*** L.	Mediterranean Region
57	Fabaceae	***Trifolium repens*** L.	Mediterranean Region
58	Fabaceae	***Trifolium subterraneum*** L.	Mediterranean Region
59	Scrophulariaceae	***Veronica arvensis*** L.	Mediterranean Region
60	Scrophulariaceae	***Veronica polita*** Fries	Mediterranean Region
61	Scrophulariaceae	***Veronica persica*** Poir.	Mediterranean Region
62	Compositae	***Vittadinia australis*** (L.) DC.	Australia

Source: Narasimhan *et. al.* 2010

Table 12: Overall activities carried out for removal of invasives*

Zone	Year	Name of the activity	Physical (Ha.)		Financial in Lakhs (Rs.)	
		Priority Watershed	Target	Achievement	Target	Achievement
Mudumalai Wildlife Sanctuary, Udhagai	1998-99	Removal of Exotic weeds (grassland management by removal of sparse wattle)	10	10	0.50	0.50
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Wildlife Sanctuary, Udhagai	1999-2000	Removal of Exotic weeds (grassland management by removal of sparse wattle)	10	10	0.50	0.50
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Wildlife Sanctuary, Udhagai	2000-01	Removal of Exotic weeds (grassland management by removal of sparse wattle)	10	10	0.50	0.50
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-

Zone	Year	Name of the activity	Physical (Ha.)		Financial in Lakhs (Rs.)	
Mudumalai Wildlife Sanctuary, Udhagai	2002-03	Removal of Exotic weeds (grassland management by removal of sparse wattle)	20	20	1.00	1.00
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity-wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Wildlife Sanctuary, Udhagai	2003-04	Removal of Exotic weeds (grassland management by removal of sparse wattle)	20	20	1.00	1.00
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Wildlife Sanctuary, Udhagai	2004-05	Removal of Exotic weeds	50	50	1.50	1.50
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Wildlife Sanctuary, Udhagai	2005-06	Removal of Exotic weeds	100	100	3.00	3.00
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-

Zone	Year	Name of the activity	Physical (Ha.)		Financial in Lakhs (Rs.)	
		Other activities	-	-	-	-
Mudumalai Wildlife Sanctuary, Udhagai	2006-07	Removal of Exotic weeds	50	50	1.50	1.50
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Wildlife Sanctuary, Udhagai	2007-08	Removal of Exotic weeds	50	50	1.50	1.50
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Tiger Reserve, Udhagai	2008-09	Removal of Exotic weeds	-	-	-	-
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Tiger Reserve, Udhagai	2009-10	Removal of Exotic weeds	200	200	10.00	10.00
		Planting of seedling (species) i.e raising taller seedlings	10,000 Nos	10,000 Nos	3.00	3.00
		Maintenance (activity wise)	-	-	-	-

Zone	Year	Name of the activity	Physical (Ha.)		Financial in Lakhs (Rs.)	
		Other activities	-	-	-	-
Mudumalai Tiger Reserve, Udhagai	2010-11	removal of Exotic weeds (grassland management by removal of sparse wattle)	50	50	2.50	2.50
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Tiger Reserve, Udhagai	2011-12	Removal of Exotic weeds	450	450	24.10	24.10
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
Mudumalai Tiger Reserve, Udhagai	2012-13	Removal of Exotic weeds (Clearing of Heavy, Medium and Light Growth) Including Mukurthi National Park	300	300	31.276	31.276
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise) i.e Shola Species	1,000 Nos	1,000 Nos	0.15	0.15
		Other activities	-	-	-	-
Mudumalai Tiger Reserve, Udhagai	2013-14	Removal of Exotic weeds (Clearing of Heavy, Medium and Light Growth) Including Mukurthi National Park	500	500	58.81	58.81

Zone	Year	Name of the activity	Physical (Ha.)		Financial in Lakhs (Rs.)	
District Forest Officer, Nilgiri South Division	2011-12	Eradication of wattle in phased manner and restoration of the area by native grass	10	10	7.500	7.500
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
		Non-priority Watershed				
		Removal of Exotic weeds	-	-	-	-
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
		Total:			**7.500**	**7.500**
		Priority Watershed				
District Forest Officer, Nilgiri South Division	2012-13	Eradication of wattle in phased manner and restoration of the area by native grass	10	10	5.100	5.100
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Eradication of wattle in phased manner and restoration of the area to its natural status (1st year maintenance)	10	10	3.500	3.500
		Other activities	-	-	-	-

Zone	Year	Name of the activity	Physical (Ha.)		Financial in Lakhs (Rs.)	
		Non-priority Watershed	-	-	-	-
		Removal of Exotic weeds	-	-	-	-
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Other activities	-	-	-	-
		Total:			**8.600**	**8.600**
		Priority Watershed				
District Forest Officer, Nilgiri South Division	2013-14	Eradication of wattle in phased manner and restoration of the area by native grass	15	15	9.000	9.000
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-
		Eradication of wattle in phased manner and restoration of the area to its natural status (1st year maintenance)	10	10	3.500	3.500
		Eradication of wattle in phased manner and restoration of the area to its natural status (2nd year maintenance)	10	10	2.000	2.000
		Other activities	-	-	-	-
		Non-priority Watershed				
		Removal of Exotic weeds	-	-	-	-
		Planting of seedling (species)	-	-	-	-
		Maintenance (activity wise)	-	-	-	-

Zone	Year	Name of the activity	Physical (Ha.)		Financial in Lakhs (Rs.)	
		Other activities	-	-	-	-
		Total:			14.5	14.5
		Priority Watershed				
District Forest Officer, Nilgiri North Division	2013-14	Removal of Exotic weeds	20	20	2.40	2.40
		Planting of seedling (species wise)	30	30	0.90	0.90
		i.	Grassland Development	-	-	-
		ii.	1. *Cenchrus*	-	-	-
		iii.	2. *Stylosanthus hamata*	-	-	-
		Maintenance (activity wise)	Road avenue Planting	-	-	-
		i.	800 Nos	800 Nos	1.04	1.04
		ii.	-	-	-	-
		iii.	-	-	-	-
		Other Activities	-	-	-	-
		i. 2nd Year Maintenance	5	5	0.06	0.06
		ii. Nursery	58,000 Nos	58,000 Nos	1.16	1.16
		iii.	-	-	-	-
		Non-priority Watershed				
		Removal of Exotic weeds	240	240	14.40	14.40
		Planting of seedling (species)	200	200	6.00	6.00

Zone	Year	Name of the activity	Physical (Ha.)		Financial in Lakhs (Rs.)	
		i.	Grassland Development	-	-	-
		ii.	3. *Cenchrus*	-	-	-
		iii.	4. *Stylosanthus hamata*	-	-	-
		Maintenance (activity wise)	-	-	-	-
		i. Nursery	53,000 Nos	53,000 Nos	1.07	1.07
		ii.	-	-	-	-
		iii.	-	-	-	-
		Other activities	-	-	-	-
		i.	-	-	-	-
		Ii	-	-	-	-
		iii.	-	-	-	-
		Total:			27.03	27.03

* sourced from Tamilnadu Forest Department

Table 13: Geo coordinates of all the plots studied

Plot	Vegetation	Cornerstones	Elevation (m ASL)	Latitude °N	Longitude °E
Teppakadu (Control)	Decidious	1A	936	11.6095	76.5738
		1B	938	11.6095	76.5746
		1D	934	11.6087	76.5738
		1C	947	11.6088	76.5746
		1E	940	11.6091	76.5742
Kargudi	Deciduous	2A	887	11.5827	76.5694
		2B	875	11.5824	76.5702
		1C	947	11.5817	76.5699
		2D	889	11.5819	76.569
		2E	875	11.5822	76.5696
Masinagudi (Periyakulam)	Deciduous	3A	879	11.5771	76.5781
		3B	881	11.5773	76.5789
		3C	880	11.5764	76.579
		3D	887	11.5761	76.5782
		3E	873	11.5767	76.5785
Teppakadu (Camp)	Deciduous	4A	867	11.5835	76.5859
		4B	852	11.5835	76.5867
		4C	862	11.5826	76.5869
		4D	865	11.5825	76.5861
		4E	855	11.583	76.5864
Masinagudi (Maanboard)	Deciduous	5A	894	11.5797	76.6031
		5B	889	11.5796	76.6039
		5C	885	11.5788	76.604
		5D	906	11.5789	76.6031
		5E	892	11.5792	76.6035
Jagglikadavu (Control)	Scrub	6A	857	11.5743	76.7075
		6B	866	11.5745	76.7083
		6C	871	11.5737	76.7085
		6D	858	11.5735	76.7077
		6E	866	11.5739	76.708
Segur	Scrub	7A	887	11.5394	76.7426
		7B	900	11.5397	76.7433
		7C	903	11.539	76.7437
		7D	895	11.5385	76.7429
		7E	898	11.5391	76.7432
Singara	Scrub	8A	894	11.5394	76.7465
		8B	891	11.5391	76.7472
		8C	887	11.5383	76.7469

Plot	Vegetation	Cornerstones	Elevation (m ASL)	Latitude °N	Longitude °E
		8D	894	11.5386	76.7461
		8E	890	11.5388	76.7466
Kulimundh	Montane	9A	2093	11.4917	76.6126
		9B	2073	11.4916	76.6131
		9C	2106	11.491	76.613
		9D	2103	11.491	76.6125
		9E	2091	11.4913	76.6128
Glenmorgan (Pavermund)	Montane	10A	2086	11.482	76.6103
		10B	2097	11.4815	76.6111
		10C	2073	11.4809	76.6106
		10D	2070	11.4812	76.6098
		10E	2080	11.4814	76.6105
Naduvattam	Montane	11A	2186	11.4293	76.5362
		11B	2184	11.429	76.537
		11C	2222	11.4282	76.5367
		11D	2214	11.4284	76.5358
		11E	2207	11.4287	76.5364
Naduvattam (Control)	Montane	12A	2303	11.4095	76.5309
		12B	2313	11.4094	76.5317
		12C	2329	11.4085	76.5316
		12D	2293	11.4086	76.5308
		12E	2312	11.409	76.5313

Annexure III

Pictures from montane habitat

Emergence and maturing of *Ageratina* post-removal of Wattle

Indigenous species replacement efforts in Glenmorgan, Pykara

Rhododendron (indigenous) sapling emerging from the cleared area

Annexure III

Pictures from deciduous forest habitat

Lantana growth in the background against the clearance (Kargudi)

Cleared area absent regeneration in summer (Teppakadu)

Cassia fistula – indigenous species recruitment

Dense growth of *Lantana* and *Chromolaena* in Masinagudi

Annexure III

Pictures from scrubland habitat

A Segur habitat invaded by Lantana

Recruitment of Cactus after the removal practice

Reconnaissance Survey

Care Earth Trust Team has done the reconnaissance survey for selecting the study area in selected forest divisions of The Nilgiris and in Mudumalai Tiger Reserve. Under various schemes, the Tamilnadu Forest Department has carried out the action of removing invasive alien species (IAS) in the district of Nilgiris. Project Tiger and Hill Area Development Programme (HADP) were the two prime schemes under which the works on removing invasive species were carried out. This pilot survey by Care Earth is to carry out the work involving assessment of the biological impacts in the area where eradication or uprooting of the invasive plants has been carried out.

Table 14: Tree diversity in the sample plots

Forest Range	Plot Location	Vegetation	Species Richness	Simpson's Index (D)	Shannon Index (H')	Pielou Evenness (J')	Stand Basal Area (m^2)	IAS cover %
Singara	Mayilarappatti	Scrub	22	0.159	2.340	0.757	41.099	12
Segur	Mayilarappatti	Scrub	23	0.139	2.431	0.775	23.520	16
Teppakadu	Camp	Dry Deciduous	13	0.128	2.224	0.895	83.294	8
Kargudi	Kalhalla	Dry Deciduous	14	0.223	1.890	0.716	175.239	24
Masinagudi	Periyakulam	Dry Deciduous	7	0.396	1.193	0.613	47.422	57
Masinagudi	Maan board	Mixed Deciduous	12	0.394	1.403	0.653	66.776	70
Pykara	Glenmorgan	Riverine Shola	14	0.104	2.413	0.914	23.259	29
Pykara	Kulimundh	Shola	17	0.093	2.554	0.901	77.180	22
Naduvattam	Carriot Shola	Shola	15	0.121	2.351	0.868	49.205	12

Table 15: Importance value index of the woody species found in montane shola habitats

Family	Tree Species Name	Density	Frequency	Basal Area (m^2)	Relative Density	Relative Frequency	Relative Basal Area	IV Index*
Mimosaceae	***Acacia melanoxylon*** R. Br.	22	2	3.733	9.735	4.348	24.611	38.693
Myrtaceae	***Syzygium densiflorum*** Wall ex. Wight & Arn.	15	2	2.376	6.637	4.348	15.664	26.649
Ericaceae	***Rhododendron arboreum*** J.E. Smith subsp. ***nilagirium*** (Zenk.) Tagg.	21	2	0.893	9.292	4.348	5.890	19.529
Sabiaceae	***Meliosma simplicifolia*** (Roxb.) Walp. subsp. ***Simplicifolia***	10	1	1.583	4.425	2.174	10.437	17.036
Symplocaceae	***Symplocos cochinchinensis*** (Lour.) Moore	11	2	1.101	4.867	4.348	7.261	16.477

Family	Tree Species Name	Density	Frequency	Basal Area (m^2)	Relative Density	Relative Frequency	Relative Basal Area	IV Index*
Myrsinaceae	***Myrsine wightiana*** Wall. ex. A. DC.	20	2	0.424	8.850	4.348	2.793	15.990
Staphyleaceae	***Turpinia cochinchinensis*** (Lour.) Merr.	11	2	0.578	4.867	4.348	3.810	13.025
Daphniphyllaceae	***Daphniphyllum neilgherrense*** (Wight) K. Rosenth.	8	3	0.300	3.540	6.522	1.977	12.038
Theaceae	***Eurya nitida*** Korth	6	3	0.331	2.655	6.522	2.185	11.361
Berberidaceae	***Mahonia leschenaultii*** (Wall. ex Wight & Arn.) Takeda	10	2	0.111	4.425	4.348	0.732	9.505
Vacciniaceae	***Vaccinium neilgherrense*** Wight	12	1	0.250	5.310	2.174	1.649	9.133
Myrtaceae	***Syzygium alternifolium*** (Wight) Walp.	7	1	0.567	3.097	2.174	3.735	9.006
Lauraceae	***Litsea quinqueflora*** (Dennst.) Suresh	12	1	0.095	5.310	2.174	0.626	8.110
Cupressaceae	***Cupressus macrocarpa*** Hartw.	3	1	0.679	1.327	2.174	4.476	7.977
Aquifoliaceae	***Ilex denticulata*** Wall ex Wight	4	2	0.137	1.770	4.348	0.901	7.019
Lauraceae	***Litsea floribunda*** (Blume) Gamble	4	2	0.099	1.770	4.348	0.651	6.768
Rosaceae	***Photinia integrifolia*** Lindl.	8	1	0.130	3.540	2.174	0.856	6.570
Compositae	***Vernonia arborea*** Buch.-Ham.	2	1	0.478	0.885	2.174	3.150	6.209
Caprifoliaceae	***Viburnum erubescens*** Wall. ex DC.	6	1	0.207	2.655	2.174	1.364	6.193
Icacinaceae	***Nothapodytes nimmoniana*** (Graham) Mabberley	6	1	0.110	2.655	2.174	0.722	5.551
Caprifoliaceae	***Viburnum punctatum*** Buch. - Ham. ex D. Don	2	2	0.017	0.885	4.348	0.111	5.344
Sabiaceae	***Meliosma pinnata*** (Roxb.) Maxim. subsp. ***barbulata*** (Cufod.) Beus.	2	1	0.306	0.885	2.174	2.017	5.076
Solanaceae	***Cestrum aurantiacum*** Lindl.	5	1	0.007	2.212	2.174	0.045	4.431
Araliaceae	***Schefflera racemosa*** (Wight) Harms	1	1	0.264	0.442	2.174	1.738	4.354
Lauraceae	***Litsea wightiana*** (Nees) Hook.f.	4	1	0.055	1.770	2.174	0.364	4.307
Lauraceae	***Cinnamomum sulphuratum*** Nees	4	1	0.043	1.770	2.174	0.285	4.228

Family	Tree Species Name	Density	Frequency	Basal Area (m^2)	Relative Density	Relative Frequency	Relative Basal Area	IV Index*
Myrsinaceae	***Rapanea capitellata*** (Wall.) Mez	3	1	0.034	1.327	2.174	0.225	3.726
Magnoliaceae	***Michelia nilagirica*** Zenk.	2	1	0.072	0.885	2.174	0.472	3.530
Lauraceae	***Cinnamomum wightii*** Meisner	1	1	0.086	0.442	2.174	0.567	3.184
Elaeagnaceae	***Elaeagnus conferta*** Roxb.	2	1	0.015	0.885	2.174	0.096	3.155
Lauraceae	***Actinodaphne lawsonii*** Gamble	1	1	0.071	0.442	2.174	0.471	3.087
Euphorbiaceae	***Glochidion neilgherrense*** Wight	1	1	0.018	0.442	2.174	0.121	2.737

* Importance Value Index

Table 16: Importance value index of the woody species found in deciduous habitats

Family	Tree Species Name	Density	Frequency	Basal Area (m^2)	Relative Density	Relative Frequency	Relative Basal Area	IV Index*
Combretaceae	***Anogeissus latifolia*** (Roxb. Ex DC.) Wall ex Guill. & Perr.	112	4	10.745	39.858	8.696	28.441	76.995
Verbenaceae	***Tectona grandis*** L.f.	43	3	8.195	15.302	6.522	21.693	43.517
Combretaceae	***Terminalia elliptica*** Willd.	42	4	4.951	14.947	8.696	13.104	36.747
Fabaceae	***Dalbergia latifolia*** Roxb.	22	4	2.822	7.829	8.696	7.469	23.994
Rubiaceae	***Hymenodictyon orixense*** (Roxb.) Mabberley	5	3	2.779	1.779	6.522	7.357	15.658
Lythraceae	***Lagerstroemia microcarpa*** Wight	9	3	1.857	3.203	6.522	4.914	14.639
Fabaceae	***Butea monosperma*** (Lam.) Taub.	8	2	0.725	2.847	4.348	1.918	9.113
Sapindaceae	***Schleichera oleosa*** (Lour.) Oken	6	2	0.992	2.135	4.348	2.626	9.109
Caesalpiniaceae	***Cassia fistula*** L.	6	3	0.094	2.135	6.522	0.248	8.905

Family	Tree Species Name	Density	Frequency	Basal Area (m²)	Relative Density	Relative Frequency	Relative Basal Area	IV Index*
Verbenaceae	***Premna tomentosa*** Willd.	2	2	0.080	0.660	4.44	0.826	5.930
Rubiaceae	***Gardenia gummifera*** L.	6	1	0.157	1.980	2.22	1.631	5.833
Mimosaceae	***Albizia amara*** (Roxb.) Boivin	1	1	0.315	0.330	2.22	3.270	5.822
Caesalpiniaceae	***Cassia fistula*** L.	2	2	0.025	0.660	4.44	0.258	5.363
Mimosaceae	***Mimosa intsia*** L.	4	1	0.011	1.320	2.22	0.111	3.653
Mimosaceae	***Albizia lebbeck*** (L.) Willd.	1	1	0.088	0.330	2.22	0.910	3.463
Rutaceae	***Naringi crenulata*** (Roxb.) Nicolson	1	1	0.031	0.330	2.22	0.317	2.870
Rubiaceae	***Capparis divaricata*** Lam.	1	1	0.003	0.330	2.22	0.027	2.579

* Importance Value Index

Table 18: Checklist of plants found in Deciduous habitat

S.No	Family	Species Name	Habit	Origin
1	Acanthaceae	***Justicia procumbens*** L.	Herb	Indigenous
2	Acanthaceae	***Justicia simplex*** D. Don	Herb	Indigenous
3	Acanthaceae	***Rungia pectinata*** (L.) Nees	Herb	Indigenous
4	Acanthaceae	***Thunbergia fragrans*** Roxb.	Climber	Indigenous
5	Amaranthaceae	***Achyranthes aspera*** L.	Herb	Indigenous
6	Amaranthaceae	***Alternanthera paronychioides*** A.St.	Herb	Tropical America
7	Amaranthaceae	***Alternanthera pungens*** Kunth	Herb	Tropical America
8	Amaranthaceae	***Amaranthus spinosus*** L.	Herb	Indigenous
9	Amaranthaceae	***Amaranthus viridis*** L.	Herb	Indigenous
10	Amaranthaceae	***Gomphrena serrata*** L.	Herb	Tropical America
11	Amaryllidaceae	***Crinum asiaticum*** L.	Herb	Indigenous
12	Apocynaceae	***Aganosma cymosa*** (Roxb.) G.Don	Climber	Indigenous
13	Apocynaceae	***Wrightia tinctoria*** (Roxb.) R.Br.	Sapling	Indigenous
14	Asclepiadaceae	***Asclepias curassavica*** L.	Herb	Tropical America
15	Asclepiadaceae	***Tylophora indica*** (Burm.f.) Merr.	Climber	Indigenous
16	Asparagaceae	***Asparagus racemosus*** Willd.	Straggler	Indigenous
17	Asteraceae	***Ageratum conyzoides*** L.	Herb	Tropical America
18	Asteraceae	***Bidens pilosa*** L.	Herb	Tropical America
19	Asteraceae	***Bidens triplinervia*** H.B.K.	Herb	Tropical America
20	Asteraceae	***Blainvillea acmella*** (L.) Philipson	Herb	Tropical America
21	Asteraceae	***Chromolaena odorata*** (L.) King & Robinson	Shrub	Tropical America
22	Asteraceae	***Conyza bonariensis*** (L.) Cronquist	Herb	Tropical America
23	Asteraceae	***Elephantopus scaber*** L.	Herb	Indigenous
24	Asteraceae	***Galinsoga parviflora*** Cav.	Herb	Tropical America
25	Asteraceae	***Lagascea mollis*** Cav.	Herb	Tropical America
26	Asteraceae	***Parthenium hysterophorus*** L.	Herb	Tropical America
27	Asteraceae	***Sigesbeckia orientalis*** L.	Herb	Indigenous
28	Asteraceae	***Spilanthes calva*** DC.	Herb	Indigenous
29	Asteraceae	***Synedrella nodiflora*** (L.) Gaertn.	Herb	Tropical America
30	Asteraceae	***Vernonia cinerea*** (L.) Less.	Herb	Tropical America
31	Asteraceae	***Crassocephalum crepidioides*** (Benth.) S. Moore	Herb	Tropical Africa
32	Boraginaceae	***Cordia obliqua*** Willd.	Sapling	Indigenous
33	Boraginaceae	***Cynoglossum zeylanicum*** (Vahl ex Hornem.) Thunb. ex Lehm.	Herb	Indigenous
34	Caesalpiniaceae	***Bauhinia racemosa*** Lam.	Sapling	Indigenous
35	Caesalpiniaceae	***Cassia fistula*** L.	Sapling	Indigenous
36	Caesalpiniaceae	***Senna auriculata*** (L.) Roxb.	Shrub	Indigenous
37	Caesalpiniaceae	***Senna occidentalis*** (L.) Link	Shrub	Indigenous
38	Caesalpiniaceae	***Senna tora*** (L.) Roxb.	Herb	Indigenous
39	Caesalpiniaceae	***Senna uniflora*** (Mill.) H.S. Irwin & Barneby	Herb	Tropical America
40	Celastraceae	***Cassine glauca*** (Rottb.) Kuntze	Sapling	Indigenous

S.No	Family	Species Name	Habit	Origin
41	Combretaceae	***Terminalia elliptica*** Willd.	Sapling	Indigenous
42	Commelinaceae	***Commelina benghalensis*** L.	Herb	Indigenous
43	Commelinaceae	***Commelina diffusa*** Burm	Herb	Indigenous
44	Commelinaceae	***Commelina wightii*** R. Rao	Herb	Indigenous
45	Commelinaceae	***Cyanotis cristata*** (L.) D. Don	Herb	Indigenous
46	Commelinaceae	***Murdannia lanuginosa*** (Wall ex Clarke) Beueckner	Herb	Indigenous
47	Convolvulaceae	***Argyreia cuneata*** (Willd.) Ker-Gawl.	Shrub	Indigenous
48	Convolvulaceae	***Argyreia elliptica*** (Roth) Choisy	Climber	Indigenous
49	Convolvulaceae	***Argyreia hirsuta*** Wight & Arn.	Climber	Indigenous
50	Convolvulaceae	***Ipomoea parasitica*** (Kunth) G. Don	Climber	Tropical America
51	Cucurbitaceae	***Cucumis hardwickii*** Royle	Herb	Indigenous
52	Cucurbitaceae	***Diplocyclos palmatus*** (L.) Jeffrey	Climber	Indigenous
53	Cucurbitaceae	***Momordica charantia*** L.	Climber	Indigenous
54	Cyperaceae	***Bulbostylis barbata*** (Rottb.) Clarke	Sedge	Indigenous
55	Cyperaceae	***Cyperus compressus*** L.	Sedge	Indigenous
56	Cyperaceae	***Cyperus difformis*** L.	Sedge	Indigenous
57	Cyperaceae	***Cyperus diffusus*** Vahl.	Sedge	Indigenous
58	Cyperaceae	***Kylinga bulbosa*** P. Beavu.	Sedge	Indigenous
59	Cyperaceae	***Kyllingia nemoralis*** (J. R. & G. Forst.) Dandy ex Hutchinson & Dalziel	Sedge	Indigenous
60	Cyperaceae	***Mariscus paniceus*** (Rottboell.) Vahl	Sedge	Indigenous
61	Ebenaceae	***Diospyros montana*** Roxb.	Sapling	Indigenous
62	Eriocaulaceae	***Eriocaulon quinquangulare*** L.	Herb	Indigenous
63	Euphorbiaceae	***Acalypha ciliata*** Forssk.	Herb	Indigenous
64	Euphorbiaceae	***Euphorbia hirta*** L.	Herb	Indigenous
65	Euphorbiaceae	***Flueggea leucopyrus*** Willd.	Shrub	Indigenous
66	Euphorbiaceae	***Jatropha curcas*** L.	Shrub	Tropical America
67	Euphorbiaceae	***Jatropha gossypifolia*** L.	Shrub	Indigenous
68	Euphorbiaceae	***Phyllanthus debilis*** Klein ex Willd.	Herb	Indigenous
69	Fabaceae	***Aeschynomene americana*** L.	Herb	Tropical America

S.No	Family	Species Name	Habit	Origin
70	Fabaceae	***Aeschynomene aspera*** L.	Herb	Indigenous
71	Fabaceae	***Alysicarpus monilifer*** (L.) DC.	Herb	Indigenous
72	Fabaceae	***Alysicarpus ovalifolius*** (Schumac) J. Leon.	Herb	Indigenous
73	Fabaceae	***Butea monosperma*** (Lam.) Taub.	Sapling	Indigenous
74	Fabaceae	***Canavalia gladiata*** (Jacq.) DC.	Liane	Indigenous
75	Fabaceae	***Centrosema pubescens*** Benth.	Climber	Tropical America
76	Fabaceae	***Crotalaria evolvuloides*** Wight ex Wight & Arn.	Herb	Indigenous
77	Fabaceae	***Dalbergia latifolia*** Roxb.	Sapling	Indigenous
78	Fabaceae	***Desmodium ferrugineum*** Wall ex Thw.	Herb	Indigenous
79	Fabaceae	***Desmodium gangeticum*** (L.) DC.	Shrub	Indigenous
80	Fabaceae	***Desmodium pulchellum*** (L.) Benth.	Herb	Indigenous
81	Fabaceae	***Desmodium triangulare*** (Retz.) Merr.	Shrub	Indigenous
82	Fabaceae	***Desmodium triflorum*** (L.) DC.	Herb	Indigenous
83	Fabaceae	***Desmodium velutinum*** (Willd.) DC.	Shrub	Indigenous
84	Fabaceae	***Flemingia macrophylla*** (Willd.) Prain ex Merr.	Shrub	Indigenous
85	Fabaceae	***Indigofera colutea*** (Buem. F.) Merr.	Herb	Indigenous
86	Fabaceae	***Indigofera linifolia*** (L.f.) Retz.	Herb	Indigenous
87	Fabaceae	***Indigofera tinctoria*** L.	Herb	Indigenous
88	Fabaceae	***Indigofera trifoliata*** L.	Herb	Indigenous
89	Fabaceae	***Melia dubia*** Cav.	Sapling	Indigenous
90	Fabaceae	***Neonotonia wightii*** (Wight & arn.) Lackey	Climber	Indigenous
91	Fabaceae	***Paracalyx scariosus*** (Roxb.) Ali	Climber	Indigenous
92	Fabaceae	***Pseudarthria viscida*** (L.) Wight & Arn.	Shrub	Indigenous
93	Fabaceae	***Rhynchosia aurea*** (Willd.) DC.	Herb	Indigenous
94	Fabaceae	***Stylosanthes hamata*** (L.) Taub.	Herb	Tropical America
95	Fabaceae	***Tephrosia villosa*** (L.) Pers.	Herb	Indigenous
96	Fabaceae	***Uraria rufescens*** (DC.) Schind.	Herb	Indigenous
97	Hypoxidaceae	***Curculigo orchioides*** Gaertn	Herb	Indigenous
98	Lamiaceae	***Hyptis suaveolens*** (L.) Poit.	Shrub	Tropical America

S.No	Family	Species Name	Habit	Origin
99	Lamiaceae	***Leucas lavandulaefolia*** Rees	Herb	Indigenous
100	Lamiaceae	***Leucas martinicensis*** (Jacq.) R. Br.	Herb	Tropical America
101	Lamiaceae	***Ocimum basilicum*** L.	Herb	Indigenous
102	Lamiaceae	***Ocimum gratissimum*** L.	Shrub	Indigenous
103	Lamiaceae	***Plectranthus mollis*** (Ait.) Spreng.	Herb	Indigenous
104	Malvaceae	***Herissantia crispa*** (L.) Brizicky	Herb	Tropical America
105	Malvaceae	***Malvastrum coromandelianum*** (L.) Garcke	Herb	Indigenous
106	Malvaceae	***Pavonia odorata*** Willd.	Herb	Indigenous
107	Malvaceae	***Pavonia zeylanica*** (L.) Cav.	Herb	Indigenous
108	Malvaceae	***Sida acuta*** Burm.f.	Herb	Indigenous
109	Malvaceae	***Sida cordata*** (Burm. f.) Borssum	Herb	Indigenous
110	Malvaceae	***Sida cordifolia*** L.	Herb	Indigenous
111	Malvaceae	***Sida rhombifolia*** L.	Herb	Indigenous
112	Malvaceae	***Urena lobata*** L. subsp. ***lobata***	Shrub	Indigenous
113	Marsileaceae	***Marsilea quadrifolia*** Linn.	Fern	Europe
114	Menispermaceae	***Cyclea peltata*** (Lam.) Hook. f. & Thoms.	Climber	Indigenous
115	Menispermaceae	***Pachygone ovata*** (Poir.) Miers ex Hook. f. & Thoms.	Climber	Indigenous
116	Menispermaceae	***Stephania japonica*** (Thunb.) Miers	Climber	Indigenous
117	Mimosaceae	***Mimosa pudica*** L.	Herb	Tropical America
118	Orchidaceae	***Geodorum densiflorum*** (Lam.) Schlte	Herb	Indigenous
119	Oxalidaceae	***Biophytum sensitivum*** (L.) DC.	Herb	Indigenous
120	Oxalidaceae	***Oxalis corniculata*** L.	Herb	Tropical America
121	Periplocaceae	***Cryptolepis buchananii*** Roem. & Schultes	Climber	Indigenous
122	Periplocaceae	***Hemidesmus indicus*** (L.) R.Br.	Herb	Indigenous
123	Plantaginaceae	***Plantago lanceolata*** L.	Herb	Eurasia
124	Poaceae	***Apluda mutica*** L.	Grass	Indigenous
125	Poaceae	***Axonopus compressus*** (Sw.) P. Beauv.	Grass	Tropical America
126	Poaceae	***Bothriochloa pertusa*** (L.) A. Camus	Grass	Indigenous
127	Poaceae	***Brachiaria remota*** (Retz.) Haines	Grass	Indigenous

S.No	Family	Species Name	Habit	Origin
128	Poaceae	***Cenchrus ciliaris L.***	Grass	Indigenous
129	Poaceae	***Chloris barbata*** Sw.	Grass	Indigenous
130	Poaceae	***Chloris dolichostachya*** Lagasca	Grass	Indigenous
131	Poaceae	***Chloris montana*** Roxb.	Grass	Indigenous
132	Poaceae	***Cynodon dactylon*** (L.) Pers.	Grass	Indigenous
133	Poaceae	***Cyrtococcum oxyphyllum*** (Steud.) Stapf.	Grass	Indigenous
134	Poaceae	***Cyrtococcum trigonum*** (Retz.) A. Camus	Grass	Indigenous
135	Poaceae	***Dactyloctenium aegyptium*** (L.) Willd.	Grass	Africa
136	Poaceae	***Dendrocalamus strictus*** (Roxb.) Nees	Grass	Indigenous
137	Poaceae	***Dichanthium annulatum*** (Forssk.) Stapf	Grass	Indigenous
138	Poaceae	***Digitaria ciliaris*** (Retz.) Koeler	Grass	Indigenous
139	Poaceae	***Echinochloa crus - galli*** (L.) P. Beauv	Grass	Indigenous
140	Poaceae	***Eleusine indica*** (L.) Gaertn	Grass	Indigenous
141	Poaceae	***Eragrostiella bifaria*** (Vahl) Bor	Grass	Indigenous
142	Poaceae	***Eragrostis gangetica*** (Roxb.) Steud.	Grass	Indigenous
143	Poaceae	***Eragrostis maderaspatana*** Bor	Grass	Indigenous
144	Poaceae	***Eragrostis tenella*** (L.) P. Beauv ex Roem. & Schultes	Grass	Indigenous
145	Poaceae	***Eragrostis viscosa*** (Retz.) Trin.	Grass	Indigenous
146	Poaceae	***Heteropogon contortus*** (L.) P Beauv	Grass	Indigenous
147	Poaceae	***Oplismenus undulatifolius*** (Ard.) P. Beauv ex Roem. & Schultes	Grass	Indigenous
148	Poaceae	***Paspalidium flavidum*** (Retz.) A. Camus	Grass	Indigenous
149	Poaceae	***Setaria verticillata*** (L.) P. Beauv	Grass	Europe
150	Poaceae	***Sporobolus indicus*** (L.) R. Br.	Grass	Indigenous
151	Poaceae	***Themeda triandra*** Forssk.	Grass	Indigenous
152	Rhamnaceae	***Ziziphus mauritiana*** Lam.	Sapling	Indigenous
153	Rhamnaceae	***Ziziphus oenoplia*** (L.) Mill.	Straggler	Indigenous
154	Rubiaceae	***Canthium coromandelicum*** (Burm. F.) Alston	Shrub	Indigenous
155	Rubiaceae	***Catunaregam spinosa*** (Thunb.) Tirvengadum	Sapling	Indigenous
156	Rubiaceae	***Hedyotis corymbosa*** (L.) Lam.	Herb	Indigenous

S.No	Family	Species Name	Habit	Origin
157	Rubiaceae	***Hedyotis puberula*** (G.Don) Arn.	Herb	Indigenous
158	Rubiaceae	***Mitracarpus villosus*** (Sw.) DC.	Herb	Tropical America
159	Rubiaceae	***Richardia scabra*** L.	Herb	Tropical America
160	Solanaceae	***Solanum nigrum*** L.	Herb	Tropical America
161	Solanaceae	***Solanum robustum*** H. Wendl.	Herb	Tropical America
162	Solanaceae	***Solanum viarum*** Dunal	Shrub	Tropical America
163	Solanaceae	***Solanum violaceum*** Ortega	Shrub	Indigenous
164	Tiliaceae	***Grewia hirsuta*** Vahl.	Shrub	Indigenous
165	Verbenaceae	***Lantana camara*** L.	Shrub	Tropical America
166	Verbenaceae	***Lantana indica*** Roxb.	Herb	Indigenous
167	Verbenaceae	***Stachytarpheta jamaicensis*** (L.) Vahl	Herb	Indigenous
168	Verbenaceae	***Tectona grandis*** L.f.	Sapling	Indigenous
169	Zingiberaceae	***Zingiber roseum*** (Roxb.) Roscoe	Herb	Indigenous

Table 19: Checklist of plants found in Scrubland habitat

S.No	Family	Species Name	Habit	Origin
1	Acanthaceae	***Barleria buxifolia*** L.	Shrub	Indigenous
2	Apocynaceae	***Carissa carandas*** L.	Shrub	Indigenous
3	Apocynaceae	***Carissa spinarum*** L.	Shrub	Indigenous
4	Apocynaceae	***Wrightia tinctoria*** (Roxb.) R.Br.	Sapling	Indigenous
5	Asclepiadaceae	***Pergularia daemia*** (Forrsk.) Chiov.	Climber	Indigenous
6	Asparagaceae	***Asparagus racemosus*** Willd.	Straggler	Indigenous
7	Asteraceae	***Parthenium hysterophorus*** L.	Herb	Tropical America
8	Boraginaceae	***Carmona retusa*** (Vahl) Masamune	Shrub	Indigenous
9	Cactaceae	***Opuntia vulgaris*** Mill.	Shrub	Tropical America
10	Caesalpiniaceae	***Cassia fistula*** L.	Sapling	Indigenous
11	Caesalpiniaceae	***Pterolobium hexapetalum*** (Roth.) Sant. & Wagh	Liane	Indigenous
12	Capparidaceae	***Capparis divaricata*** Lam.	Sapling	Indigenous
13	Capparidaceae	***Capparis sepiaria*** L.	Shrub	Indigenous
14	Capparidaceae	***Crateva adansonii*** DC.	Sapling	Indigenous
15	Commelinaceae	***Commelina wightii*** R. Rao	Herb	Indigenous
16	Convolvulaceae	***Evolvulus alsinoides*** (L.) L.	Herb	Tropical America
17	Convolvulaceae	***Evolvulus nummularius*** (L.) L.	Herb	Indigenous
18	Convolvulaceae	***Ipomoea obscura*** (L.) Ker-Gawl.	Climber	Indigenous
19	Crassulaceae	***Kalanchoe pinnata*** (Lam.) Pers.	Herb	Tropical America
20	Erythroxylaceae	***Erythroxylum monogynum*** Roxb.	Sapling	Indigenous
21	Euphorbiaceae	***Euphorbia antiquorum*** L.	Sapling	Indigenous
22	Euphorbiaceae	***Euphorbia tirucalli*** L.	Shrub	Africa
23	Euphorbiaceae	***Flueggea leucopyrus*** Willd.	Shrub	Indigenous
24	Euphorbiaceae	***Jatropha curcas*** L.	Shrub	Tropical America
25	Euphorbiaceae	***Phyllanthus reticulatus*** Poir.	Shrub	Indigenous
26	Euphorbiaceae	***Phyllanthus virgatus*** Forst.	Herb	Indigenous
27	Euphorbiaceae	***Synadenium grantii*** Hook.f.	Sapling	Tropical America
28	Euphorbiaceae	***Tragia involucrata*** L.	Herb	Indigenous
29	Fabaceae	***Indigofera tinctoria*** L.	Herb	Indigenous
30	Fabaceae	***Tephrosia purpurea*** (L.) Pers.	Herb	Indigenous
31	Fabaceae	***Tephrosia villosa*** (L.) Pers.	Herb	Indigenous
32	Hyacinthaceae	***Urginea indica*** (Roxb.) Kunth	Herb	Indigenous
33	Lamiaceae	***Leucas indica*** (L.) R.Br. ex Vatke	Herb	Indigenous
34	Lamiaceae	***Leucas martinicensis*** (Jacq.) R. Br.	Herb	Tropical America
35	Lamiaceae	***Leucas urticaefolia*** (Vahl) R.Br.	Herb	Indigenous
36	Lamiaceae	***Ocimum basilicum*** L.	Herb	Indigenous
37	Lamiaceae	***Orthosiphon thymiflorus*** (Roth) Sleensen	Herb	Indigenous
38	Malvaceae	***Abutilon indicum*** (L.) Sweet	Shrub	Indigenous
39	Malvaceae	***Herissantia crispa*** (L.) Brizicky	Herb	Tropical America
40	Malvaceae	***Hibiscus micranthus*** L.f.	Herb	Indigenous
41	Malvaceae	***Sida cordata*** (Burm. f.) Borssum	Herb	Indigenous

S.No	Family	Species Name	Habit	Origin
42	Malvaceae	***Sida cordifolia*** L.	Herb	Indigenous
43	Mimosaceae	***Acacia catechu*** (L.f.) Willd.	Sapling	Indigenous
44	Mimosaceae	***Acacia chundra*** (Roxb. ex Rottl.) Willd.	Sapling	Indigenous
45	Mimosaceae	***Acacia pennata*** (L.) Willd.	Liane	Indigenous
46	Mimosaceae	***Mimosa intsia*** L.	Liane	Indigenous
47	Moraceae	***Ficus benghalensis*** L.	Sapling	Indigenous
48	Ochnaceae	***Ochna gamblei*** King ex Brandis	Sapling	Indigenous
49	Orchidaceae	***Vanda tessellata*** (Roxb.) Hook ex. G. Don	Herb	Indigenous
50	Oxalidaceae	***Biophytum sensitivum*** (L.) DC	Herb	Indigenous
51	Poaceae	***Aristida adscensionis*** L.	Grass	Indigenous
52	Poaceae	***Aristida funiculata*** Trin & Rupr.	Grass	Indigenous
53	Poaceae	***Aristida hystrix*** L.	Grass	Indigenous
54	Poaceae	***Bothriochloa pertusa*** (L.) A. Camus	Grass	Indigenous
55	Poaceae	***Chloris barbata*** Sw.	Grass	Indigenous
56	Poaceae	***Chloris dolichostachya*** Lagasca	Grass	Indigenous
57	Poaceae	***Chloris montana*** Roxb.	Grass	Indigenous
58	Poaceae	***Cynodon dactylon*** (L.) Pers.	Grass	Indigenous
59	Poaceae	***Cyrtococcum trigonum*** (Retz.) A. Camus	Grass	Indigenous
60	Poaceae	***Dactyloctenium aegyptium*** (L.) Willd.	Grass	Tropical Africa
61	Poaceae	***Eragrostiella bifaria*** (Vahl) Bor	Grass	Indigenous
62	Poaceae	***Eragrostis tenella*** (L.) P. Beauv ex Roem. & Schultes	Grass	Indigenous
63	Poaceae	***Heteropogon contortus*** (L.) P Beauv	Grass	Indigenous
64	Poaceae	***Perotis indica*** (L.) Kuntze	Grass	Indigenous
65	Poaceae	***Sehima nervosum*** (Rottl.) Stapf	Grass	Indigenous
66	Poaceae	***Setaria verticillata*** (L.) P. Beauv	Grass	Tropical America
67	Poaceae	***Trachys muricata*** (L.) Pers ex Trin.	Grass	Indigenous
68	Rhamnaceae	***Ziziphus mauritiana*** Lam.	Sapling	Indigenous
69	Rhamnaceae	***Ziziphus oenoplia*** (L.) Mill.	Sapling	Indigenous
70	Rubiaceae	***Benkara malabarica*** (Lam.) Tirvengadum	Sapling	Indigenous

S.No	Family	Species Name	Habit	Origin
71	Rubiaceae	***Canthium coromandelicum*** (Burm. F.) Alston	Shrub	Indigenous
72	Rubiaceae	***Mitracarpus villosus*** (Sw.) DC.	Herb	Tropical Africa
73	Rutaceae	***Limonia acidissima*** L.	Sapling	Indigenous
74	Rutaceae	***Toddalia asiatica*** (L.) Lam.	Straggler	Indigenous
75	Rutaceae	***Chloroxylon swietenia*** DC.	Sapling	Indigenous
76	Sapindaceae	***Sapindus emarginatus*** Vahl	Sapling	Indigenous
77	Solanaceae	***Solanum pubescens*** Willd.	Shrub	Indigenous
78	Solanaceae	***Solanum violaceum*** Ortega	Shrub	Indigenous
79	Sterculiaceae	***Melhania incana*** Heyne ex Wight & Arn.	Herb	Indigenous
80	Verbenaceae	***Gmelina asiatica*** L.	Sapling	Indigenous
81	Verbenaceae	***Lantana camara*** L.	Shrub	Tropical America
82	Verbenaceae	***Premna tomentosa*** Willd.	Sapling	Indigenous
83	Vitaceae	***Cissus quadrangularis*** L.	Climber	Indigenous

Table 20: Checklist of plants found in Montane evergreen habitat

S.No	Family	Species Name	Habit	Origin
1	Acanthaceae	***Justicia procumbens*** L.	Herb	Indigenous
2	Acanthaceae	***Strobilanthes kunthianum*** (Nees) Anders.	Shrub	Indigenous
3	Acanthaceae	***Strobilanthes wightianus*** Nees	Shrub	Indigenous
4	Apiaceae	***Centella asiatica*** (L.) Urban	Herb	Indigenous
5	Araceae	***Arisaema leschenaultii*** Blume	Shrub	Indigenous
6	Asteraceae	***Adenostemma lavenia*** (L.) Kuntze	Herb	Indigenous
7	Asteraceae	***Ageratina adenophora*** (Spreng.) R.King & H. Robinson	Herb	Central America
8	Asteraceae	***Emilia sonchifolia*** (L.) DC.	Herb	Indigenous
9	Asteraceae	***Gamochaeta pensylvanica*** (Willd.) Cavrera	Herb	Tropical America
10	Asteraceae	***Hypochoeris glabra*** L.	Herb	Europe
11	Asteraceae	***Launaea acaulis*** (Roxb.) Babc. ex Kerr	Herb	Indigenous
12	Asteraceae	***Silybum marianum*** (L.) Gaertn.	Herb	Southern Europe

S.No	Family	Species Name	Habit	Origin
13	Asteraceae	***Taraxacum officinale*** Weber	Herb	Indigenous
14	Asteraceae	***Crassocephalum crepidioides*** (Benth.) S. Moore	Shrub	Tropical Africa
15	Berberidaceae	***Mahonia leschenaultii*** (Wall. ex Wight & Arn.) Takeda	Sapling	Indigenous
16	Brassicaceae	***Cardamine hirsuta*** L.	Herb	Europe
17	Campanulaceae	***Wahlenbergia marginata*** (Thunb.) A.DC.	Herb	Indigenous
18	Caryophyllaceae	***Cerastium indicum*** Wight & Arn.	Herb	Indigenous
19	Caryophyllaceae	***Drymaria cordata*** (L.) Willd. ex Roem. & Schultes	Herb	Tropical America
20	Caryophyllaceae	***Stellaria media*** (L.) Vill.	Herb	Mediterranean
21	Clusiaceae	***Hypericum japonicum*** Thunb. ex Murr.	Herb	Indigenous
22	Convallariaceae	***Ophiopogon intermedius*** D. Don	Herb	Indigenous
23	Cucurbitaceae	***Zehneria maysorensis*** (Wight & Arn.) Arn.	Climber	Indigenous
24	Cyperaceae	***Carex baccans*** Nees	Sedge	Indigenous
25	Daphniphyllaceae	***Daphniphyllum neilgherrense*** (Wight) K. Rosenth.	Sapling	Indigenous
26	Dennstaedtiaceae	***Pteridium aquilinum*** (L.) Kuhn	Herb	Indigenous
27	Ericaceae	***Gaultheria fragrantissima*** Wall.	Shrub	Indigenous
28	Ericaceae	***Rhododendron arboreum*** J.E. Smith	Sapling	Indigenous
29	Eriocaulaceae	***Eriocaulon robustum*** Steud.	Herb	Indigenous
30	Euphorbiaceae	***Euphorbia rothiana*** Spreng.	Herb	Indigenous
31	Euphorbiaceae	***Glochidion ellipticum*** Wight	Sapling	Indigenous
32	Fabaceae	***Desmodium repandum*** (Vahl) DC.	Herb	Indigenous
33	Fabaceae	***Parochetus communis*** Buch. - Ham. ex D. Don	Herb	Indigenous
34	Fabaceae	***Smithia blanda*** Wall. ex Wight & Arn.	Herb	Indigenous
35	Fabaceae	***Trifolium dubium*** Sibth.	Herb	Mediterranean
36	Gentianaceae	***Gentiana pedicellata*** Griseb.	Herb	Indigenous
37	Gentianaceae	***Gentiana quadrifaria*** Blume	Herb	Indigenous
38	Gentianaceae	***Swertia corymbosa*** (Griseb.) Wight ex Clarke	Herb	Indigenous
39	Geraniaceae	***Erodium moschatum*** (L.) L' Herit	Herb	Europe
40	Gesneriaceae	***Didymocarpus tomentosus*** Wight	Herb	Indigenous
41	Haloragaceae	***Laurembergia coccinea*** (Blume) Kan.	Herb	Indigenous

S.No	Family	Species Name	Habit	Origin
42	Juncaceae	***Juncus effusus*** L.	Rush	Indigenous
43	Juncaceae	***Juncus inflexus*** L.	Rush	Indigenous
44	Lamiaceae	***Clinopodium umbrosum*** (M. Bieb.) K. Koch	Herb	Indigenous
45	Lamiaceae	***Isodon wightii*** (Benth.) H. Hara	Herb	Indigenous
46	Lamiaceae	***Leucas suffruticosa*** Benth.	Herb	Indigenous
47	Lamiaceae	***Leucas vestita*** Benth.	Herb	Indigenous
48	Lamiaceae	***Scutellaria violacea*** Heyne ex Benth.	Herb	Indigenous
49	Lamiaceae	***Teucrium tomentosum*** Heyne ex Benth.	Herb	Indigenous
50	Lauraceae	***Actinodaphne bourdillonii*** Gamble	Sapling	Indigenous
51	Lauraceae	***Litsea glutinosa*** (Lour.) C. Robinson	Sapling	Indigenous
52	Melastomataceae	***Osbeckia brachystemon*** Naud.	Herb	Indigenous
53	Mimosaceae	***Acacia mearnsii*** Wilde	Sapling	Australia
54	Mimosaceae	***Acacia melanoxylon*** R. Br.	Sapling	Australia
55	Myrsinaceae	***Myrsine wightiana*** Wall. ex. A. DC.	Sapling	Indigenous
56	Oleaceae	***Jasminum bignoniaceum*** Wall. ex G.Don	Herb	Indigenous
57	Orchidaceae	***Seidenfia densiflora*** (A. Rich.) Szlach.	Herb	Indigenous
58	Oxalidaceae	***Oxalis corniculata*** L.	Herb	Tropical America
59	Oxalidaceae	***Oxalis corymbosa*** DC.	Herb	Tropical America
60	Piperaceae	***Peperomia tetraphylla*** (Forst.f.) Hook. & Arn.	Herb	Indigenous
61	Piperaceae	***Piper nigrum*** L.	Climber	Indigenous
62	Plantaginaceae	***Plantago erosa*** Wall.	Herb	Eurasia
63	Poaceae	***Axonopus compressus*** (Sw.) P. Beauv.	Grass	Tropical America
64	Poaceae	***Cyrtococcum trigonum*** (Retz.) A. Camus	Grass	Indigenous
65	Poaceae	***Eragrostis nigra*** Nees ex Steud.	Grass	Indigenous
66	Poaceae	***Eragrostis unioloides*** (Retz.) Nees ex Steud.	Grass	Indigenous
67	Poaceae	***Eragrostis viscosa*** (Retz.) Trin.	Grass	Indigenous
68	Poaceae	***Eulalia phaeothrix*** (Hack.) Kuntze	Grass	Indigenous
69	Poaceae	***Ochlandra travancorica*** Benth ex Gamble	Grass	Indigenous
70	Poaceae	***Oxytenanthera monadelpha***(Thw.) Alston	Grass	Indigenous

S.No	Family	Species Name	Habit	Origin
71	Poaceae	***Pennisetum clandestinum*** Hochst.	Grass	East Africa
72	Poaceae	***Poa annua*** L.	Grass	Eurasia
73	Poaceae	***Vulpia myuros*** (L.) Gmel.	Grass	Eurasia
74	Polygonaceae	***Persicaria chinensis*** (L.) H.Gross	Herb	Indigenous
75	Polygonaceae	***Persicaria nepalensis*** (Meisn.) H.Gross	Herb	Indigenous
76	Pteridaceae	***Pityrogramma austroamericana*** Domin	Herb	Tropical America
77	Rosaceae	***Photinia integrifolia*** Lindl.	Sapling	Indigenous
78	Rosaceae	***Rubus ellipticus*** Smith	Shrub	Indigenous
79	Rosaceae	***Rubus niveus*** Thunb.	Shrub	Indigenous
80	Rubiaceae	***Hedyotis swertioides*** Hook.f.	Shrub	Indigenous
81	Rubiaceae	***Neanotis indica*** (DC.) W.H. Lewis	Herb	Indigenous
82	Rubiaceae	***Psychotria bisulcata*** Wight & Arn.	Shrub	Indigenous
83	Rubiaceae	***Psychotria nilgiriensis*** Deb & Gang.	Shrub	Indigenous
84	Rubiaceae	***Psychotria truncata*** Wall.	Shrub	Indigenous
85	Rutaceae	***Toddalia asiatica*** (L.) Lam.	Straggler	Indigenous
86	Sapindaceae	***Dodonaea viscosa*** (L.) Jacq.	Shrub	Indigenous
87	Scrophulariaceae	***Veronica polita*** Fries	Herb	Mediterranean
88	Solanaceae	***Cestrum aurantiacum*** Lindl.	Shrub	Tropical America
89	Solanaceae	***Solanum mauritianum*** Scop.	Shrub	Tropical America
90	Solanaceae	***Solanum robustum*** H. Wendl.	Shrub	South America
91	Solanaceae	***Solanum sisymbriifolium*** Lam.	Shrub	South America
92	Theaceae	***Eurya nitida*** Korth	Shrub	Indigenous
93	Theaceae	***Ternstroemia japonica*** (Thunb.) Thunb.	Sapling	Indigenous
94	Urticaceae	***Droguetia iners*** (Forssk.) Schweinf.	Herb	Indigenous
95	Urticaceae	***Urtica parviflora*** Roxb.	Herb	Europe
96	Vacciniaceae	***Vaccinium neilgherrense*** Wight	Sapling	Indigenous
97	Xyridaceae	***Xyris capensis*** Thunb.	Herb	Indigenous

Annexure V **List of Animals recorded during the survey**

Table 21: Butterflies

Butterflies			Forest Type		
S. No.	**Common Name**	**Scientific Name**	**Deciduous**	**Montane Evergreen**	**Scrubland**
1	Common Banded Awl	*Hasora chromus*	+		
2	Tiny Grass Blue	*Zizula hylax*	+		+
3	Red Pierrot	*Talicada nyseus*	+		
4	Comon Pierrot	*Castalius rosimon*†			
5	Zebra Blue	*Leptotes plinius*			+
6	Grass Jewel	*Freyeria trochylus*	+		
7	Plains Cupid	*Chilades pandava*			+
8	Gram Blue	*Euchrysops cnejus*			+
9	Common Silverline	*Spindasis vulcanus*		+	
10	Nilgiri Tiger	*Parantica nilgiriensis*		+	
11	Blue Tiger	*Tirumala limniace*	+	+	+
12	Common Nawab	*Charaxes bharata*	+	+	
13	Common Leopard	*Phalanta phalantha*	+	+	
14	Common Sailer	*Neptis hylas*	+	+	
15	Common Bushbrown	*Mycalesis perseus*	+	+	
16	Common Evening Brown	*Melanitis leda*			+
17	Blue Pansy	*Junonia orithya*			+
18	Lemon Pansy	*Junonia lemonias*	+		+
19	Chocolate Pansy	*Junonia iphita*	+	+	+
20	Danaid Eggfly	*Hypolimnas misippus*	+	+	+
21	Plain Tiger	*Danaus chrysippus*	+		+
22	Joker	*Byblia ilithyia*	+		
23	Tawny Coster	*Acraea terpsicore*	+	+	+
24	Psyche	*Leptosia nina*	+	+	+

Butterflies			Forest Type		
S. No.	**Common Name**	**Scientific Name**	**Deciduous**	**Montane Evergreen**	**Scrubland**
25	Common Grass Yellow	*Eurema hecabe*	+	+	+
26	Common Jezebel	*Delias eucharis*	+	+	
27	Common Gull	*Cepora nerissa*†	+		+
28	Mottled Emigrant	*Catopsilia pyranthe*	+	+	+
29	Common Emigrant	*Catopsilia pomona*			+
30	Southern Birdwing	*Troides minos*		+	
31	Common Lime Butterfly	*Papilio demoleus*	+	+	+
32	Crimson Rose	*Pachliopta hector*	+	+	+
		Total:	**22**	**17**	**19**

Table 22: Herpetofauna recorded from the study sites

Herpetofauna			Forest Type		
S. No	**Common Name**	**Scientific Name**	**Deciduous**	**Montane Evergreen**	**Scrubland**
1	Russell's Viper	*Daboia russelii*†	+		
2	Common Skink	*Mabuya carinata*	+		+
3	Bengal Monitor Lizard	*Varanus bengalensis*†	+		+
4	Garden Lizard	*Calotes versicolor*	+	+	+
5	Fan-throated lizard	*Sitana ponticeriana*	+		+
6	Spiny lizard	*Salea* sp.		+	
7	Shieldtails / Earth snakes	*Uropeltis* sp.		+	
8	Indian Chameleon	*Chamaeleo zeylanicus*†	+		
		Total:	**6**	**3**	**4**

Table 23: Birds (consolidated list for all the three divisions)

S. No.	Order	Family	English Name	Scientific Name	IUCN threatened category
1	Galliformes	Phasianidae	Common Quail	*Coturnix coturnix*	
2	Galliformes	Phasianidae	Grey Francolin	*Francolinus pondicerianus*	
3	Galliformes	Phasianidae	Grey Junglefowl	*Gallus sonneratii**	
4	Galliformes	Phasianidae	Indian Peafowl	*Pavo cristatus†*	
5	Galliformes	Phasianidae	Jungle Bush Quail	*Perdicula asiatica*	
6	Ciconiiformes	Ciconiidae	Woolly-necked Stork	*Ciconia episcopus*	VU
7	Pelecaniformes	Ardeidae	Indian Pond Heron	*Ardeola grayii*	
8	Pelecaniformes	Ardeidae	Little Egret	*Egretta garzetta*	
9	Suliformes	Phalacrocoracidae	Little Cormorant	*Microcarbo niger*	
10	Accipitriformes	Accipitridae	Shikra	*Accipiter badius*	
11	Accipitriformes	Accipitridae	Besra	*Accipiter virgatus*	
12	Accipitriformes	Accipitridae	White-rumped Vulture	*Gyps bengalensis†*	CR
13	Accipitriformes	Accipitridae	Brahminy Kite	*Haliastur indus*	
14	Accipitriformes	Accipitridae	Black Eagle	*Ictinaetus malayensis*	
15	Accipitriformes	Accipitridae	Black Kite	*Milvus migrans*	
16	Accipitriformes	Accipitridae	Red-headed Vulture	*Sarcogyps calvus*	CR
17	Accipitriformes	Accipitridae	Crested Serpent Eagle	*Spilornis cheela*	
18	Falconiformes	Falconidae	Common Kestrel	*Falco tinnunculus*	
19	Charadriiformes	Charadriidae	Red-wattled Lapwing	*Vanellus indicus*	
20	Charadriiformes	Charadriidae	Yellow-wattled Lapwing	*Vanellus malabaricus*	
21	Charadriiformes	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	
22	Columbiformes	Columbidae	Common Pigeon	*Columba livia†*	
23	Columbiformes	Columbidae	Spotted Dove	*Spilopelia chinensis*	
24	Columbiformes	Columbidae	Laughing Dove	*Spilopelia senegalensis*	
25	Psittaciformes	Psittacidae	Plum-headed Parakeet	*Psittacula cyanocephala*	
26	Psittaciformes	Psittacidae	Rose-ringed Parakeet	*Psittacula krameri*	

S. No.	Order	Family	English Name	Scientific Name	IUCN threatened category
27	Psittaciformes	Psittaculidae	Blue-winged Parakeet	*Psittacula columboides**	
28	Cuculiformes	Cuculidae	Jacobin Cuckoo	*Clamator jacobinus*	
29	Cuculiformes	Cuculidae	Asian Koel	*Eudynamys scolopaceus*	
30	Cuculiformes	Cuculidae	Common Hawk-Cuckoo	*Hierococcyx varius*	
31	Apodiformes	Apodidae	Asian Palm Swift	*Cypsiurus balasiensis*	
32	Coraciiformes	Alcedinidae	Common Kingfisher	*Alcedo atthis*	
33	Coraciiformes	Alcedinidae	Pied Kingfisher	*Ceryle rudis*	
34	Coraciiformes	Alcedinidae	White-throated Kingfisher	*Halcyon smyrnensis*	
35	Coraciiformes	Alcedinidae	Stork-billed Kingfisher	*Pelargopsis capensis*	
36	Coraciiformes	Coraciidae	Indian Roller	*Coracias benghalensis*	
37	Coraciiformes	Meropidae	Green Bee-eater	*Merops orientalis*	
38	Coraciiformes	Meropidae	Blue-tailed Bee-eater	*Merops philippinus*	
39	Coraciiformes	Meropidae	Blue-bearded Bee-eater	*Nyctyornis athertoni*	
40	Bucerotiformes	Bucerotidae	Indian Grey Hornbill	*Ocyceros birostris*	
41	Bucerotiformes	Upupidae	Eurasian Hoopoe	*Upupa epops*	
42	Piciformes	Megalaimidae	Coppersmith Barbet	*Megalaima haemacephala*	
43	Piciformes	Megalaimidae	White-cheeked Barbet	*Megalaima viridis**	
44	Piciformes	Megalaimidae	Brown-headed Barbet	*Megalaima zeylanica*	
45	Piciformes	Picidae	White-naped Woodpecker	*Chrysocolaptes festivus*	
46	Piciformes	Picidae	Brown-capped Pygmy Woodpecker	*Dendrocopos nanus*	
47	Piciformes	Picidae	Lesser Goldenback	*Dinopium benghalense*	
48	Piciformes	Picidae	Lesser Yellownape	*Picus chlorolophus*	
49	Piciformes	Picidae	Streak-throated Woodpecker	*Picus xanthopygaeus*	
50	Passeriformes	Acrocephalidae	Blyth's Reed Warbler	*Acrocephalus dumetorum*	
51	Passeriformes	Acrocephalidae	Clamorous Reed Warbler	*Acrocephalus stentoreus*	
52	Passeriformes	Aegithinidae	Common Iora	*Aegithina tiphia*	
53	Passeriformes	Alaudidae	Ashy-crowned Sparrow-Lark	*Eremopterix griseus*	

S. No.	Order	Family	English Name	Scientific Name	IUCN threatened category
54	Passeriformes	Alaudidae	Malabar Lark	*Galerida malabarica**	
55	Passeriformes	Alaudidae	Jerdon's Bush Lark	*Mirafra affinis*	
56	Passeriformes	Campephagidae	Large Cuckooshrike	*Coracina macei*	
57	Passeriformes	Campephagidae	Black-headed Cuckooshrike	*Coracina melanoptera*	
58	Passeriformes	Campephagidae	Small Minivet	*Pericrocotus cinnamomeus*	
59	Passeriformes	Chloropseidae	Jerdon's Leafbird	*Chloropsis jerdoni*	
60	Passeriformes	Cisticolidae	Common Tailorbird	*Orthotomus sutorius*	
61	Passeriformes	Cisticolidae	Plain Prinia	*Prinia inornata*	
62	Passeriformes	Cisticolidae	Ashy Prinia	*Prinia socialis*	
63	Passeriformes	Cisticolidae	Jungle Prinia	*Prinia sylvatica*	
64	Passeriformes	Corvidae	Large-billed Crow	*Corvus macrorhynchos*	
65	Passeriformes	Corvidae	House Crow	*Corvus splendens*	
66	Passeriformes	Corvidae	Rufous Treepie	*Dendrocitta vagabunda*	
67	Passeriformes	Dicruridae	Bronzed Drongo	*Dicrurus aeneus*	
68	Passeriformes	Dicruridae	White-bellied Drongo	*Dicrurus caerulescens*	
69	Passeriformes	Dicruridae	Ashy Drongo	*Dicrurus leucophaeus*	
70	Passeriformes	Dicruridae	Black Drongo	*Dicrurus macrocercus*	
71	Passeriformes	Dicruridae	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	
72	Passeriformes	Estrildidae	Indian Silverbill	*Euodice malabarica*	
73	Passeriformes	Estrildidae	Scaly-breasted Munia	*Lonchura punctulata*	
74	Passeriformes	Estrildidae	White-rumped Munia	*Lonchura striata*	
75	Passeriformes	Hirundinidae	Red-rumped Swallow	*Cecropis daurica*	
76	Passeriformes	Hirundinidae	Barn Swallow	*Hirundo rustica*	
77	Passeriformes	Zosteropidae	Oriental White-eye	*Zosterops palpebrosus*	
78	Passeriformes	Irenidae	Asian Fairy-bluebird	*Irena puella*	
79	Passeriformes	Laniidae	Brown Shrike	*Lanius cristatus*	
80	Passeriformes	Laniidae	Long-tailed Shrike	*Lanius schach*	

S. No.	Order	Family	English Name	Scientific Name	IUCN threatened category
81	Passeriformes	Laniidae	Bay-backed Shrike	*Lanius vittatus*	
82	Passeriformes	Leiothrichidae	Jungle Babbler	*Turdoides striata*	
83	Passeriformes	Monarchidae	Asian Paradise Flycatcher	*Terpsiphone paradisi*	
84	Passeriformes	Motacillidae	Nilgiri Pipit	*Anthus nilghiriensis**	VU
85	Passeriformes	Motacillidae	Paddyfield Pipit	*Anthus rufulus*	
86	Passeriformes	Motacillidae	Pipit	*Anthus* sp.	
87	Passeriformes	Motacillidae	Grey Wagtail	*Motacilla cinerea*	
88	Passeriformes	Motacillidae	White-browed Wagtail	*Motacilla maderaspatensis*	
89	Passeriformes	Muscicapidae	Oriental Magpie-Robin	*Copsychus saularis*	
90	Passeriformes	Muscicapidae	Nilgiri Flycatcher	*Eumyias albicaudatus**	
91	Passeriformes	Muscicapidae	Verditer Flycatcher	*Eumyias thalassinus*	
92	Passeriformes	Muscicapidae	Asian Brown Flycatcher	*Muscicapa dauurica*	
93	Passeriformes	Muscicapidae	Brown-breasted Flycatcher	*Muscicapa muttui*	
94	Passeriformes	Muscicapidae	Pied Bush Chat	*Saxicola caprata*	
95	Passeriformes	Muscicapidae	Stonechat	*Saxicola* sp.	
96	Passeriformes	Muscicapidae	Indian Robin	*Saxicoloides fulicatus*	
97	Passeriformes	Nectariniidae	Purple Sunbird	*Cinnyris asiaticus*	
98	Passeriformes	Nectariniidae	Loten's Sunbird	*Cinnyris lotenius*	
99	Passeriformes	Nectariniidae	Crimson-backed Sunbird	*Leptocoma minima**	
100	Passeriformes	Nectariniidae	Purple-rumped Sunbird	*Leptocoma zeylonica*	
101	Passeriformes	Oriolidae	Indian Golden Oriole	*Oriolus kundoo*	
102	Passeriformes	Paridae	Great Tit	*Parus major*	
103	Passeriformes	Passeridae	House Sparrow	*Passer domesticus*	
104	Passeriformes	Passeridae	Yellow-throated Sparrow	*Gymnoris xanthocollis*	
105	Passeriformes	Phylloscopidae	Greenish Warbler	*Phylloscopus* sp.	
106	Passeriformes	Pittidae	Indian Pitta	*Pitta brachyura*	
107	Passeriformes	Pycnonotidae	Black Bulbul	*Hypsipetes leucocephalus*	

S. No.	Order	Family	English Name	Scientific Name	IUCN threatened category
108	Passeriformes	Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer*	
109	Passeriformes	Pycnonotidae	Red-whiskered Bulbul	*Pycnonotus jocosus*	
110	Passeriformes	Pycnonotidae	White-browed Bulbul	*Pycnonotus luteolus*	
111	Passeriformes	Rhipiduridae	White-throated Fantail	*Rhipidura albicollis*	
112	Passeriformes	Sittidae	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*	
113	Passeriformes	Sittidae	Velvet-fronted Nuthatch	*Sitta frontalis*	
114	Passeriformes	Sturnidae	Common Myna	*Acridotheres tristis*	
115	Passeriformes	Sturnidae	Jungle Myna	*Acridotheres fuscus*	
116	Passeriformes	Sturnidae	Brahminy Starling	*Sturnia pagodarum*	
117	Passeriformes	Sylviidae	Lesser Whitethroat	*Sylvia curruca*	
118	Passeriformes	Tephrodornithidae	Bar-winged Flycatcher-shrike	*Hemipus picatus*	
119	Passeriformes	Tephrodornithidae	Common Woodshrike	*Tephrodornis pondicerianus*	
120	Passeriformes	Turdidae	Malabar Whistling Thrush	*Myophonus horsfieldii*	
121	Passeriformes	Turdidae	Indian Blackbird	*Turdus simillimus*	
122	Passeriformes	Turdidae	Orange-headed Thrush	*Zoothera citrina*	

Table 24: Mammals recorded from the study sites

	Mammals			Forest Type		
S.No	Common Name	Scientific Name	IUCN Category	Deciduous	Montane Evergreen	Scrubland
1	Bonnet Macaque	*Macaca radiata*†		+		+
2	Tufted gray Langur/ Common Langur	*Semnopithecus priam*†		+	+	+
3	Asian Elephant	*Elephas maximus*†	EN	+		+
4	Indian Chevrotain	*Moschiola indica*†		+		
5	Indian Muntjac	*Muntiacus muntjac*†		+		+
6	Sambar	*Rusa unicolor*†	VU	+	+	+
7	Spotted Deer	*Axis axis*		+	+	+

	Mammals			Forest Type		
S.No	Common Name	Scientific Name	IUCN Category	Deciduous	Montane Evergreen	Scrubland
8	Gaur	*Bos gaurus*†	VU	+	+	+
9	Indian Wild Pig	*Sus scrofa*†		+	+	+
10	Tiger	*Panthera tigris*†	EN	+	+	+
11	Common Leopard	*Panthera pardus*†	VU	+	+	+
12	Grey Mongoose	*Herpestes edwardsii*†		+		+
13	Ruddy Mongoose	*Herpestes smithii*†		+		
14	Sloth Bear	*Melursus ursinus*†	VU	+		+
15	Indian Hare	*Lepus nigricollis*†		+		+
16	Indian Giant Squirrel	*Ratufa indica*†		+	+	+
17	Three-striped Palm Squirrel	*Funambulus palmarum*		+	+	+
18	Indian Crested Porcupine	*Hystrix indica*†				+
19	Small Indian Civet	*Viverricula indica*†				+
20	Wild Dog	*Cuon alpinus*†	EN			+
21	Nilgiri Langur	*Trachypithecus johnii*†	VU		+	
22	Southern Tree Shrew	*Anathana ellioti*			+	
		Total no. of species recorded:		**17**	**11**	**18**

*-represents the species is endemic to South India/Western Ghats/part of it.

†-represents the species is protected under Schedule category of Wildlife (Protection) Act, 1972

IUCN threatened categories; VU-Vulnerable, EN-Endangered, CR-Critically Endangered

Table 25: Bird species richness: plot-wise

Plot area	No. of Bird Species
Segur	94
Singara	92
Pykara (Kulimundh)	46
Pykara (Pavermundh)	46
Masinagudi (Maan Board)	58
Masinagudi (Periakulam)	78
Teppakadu	76
Kargudi	79
Naduvattam	29

Table 26: Birds diversity plot-wise

Scrubland Habitat - Segur		
S.No.	**English Name**	**Scientific Name**
1	Common Quail	*Coturnix coturnix*
2	Grey Francolin	*Francolinus pondicerianus*
3	Grey Junglefowl	*Gallus sonneratii*
4	Indian Peafowl	*Pavo cristatus*
5	Jungle Bush Quail	*Perdicula asiatica*
6	Woolly-necked Stork	*Ciconia episcopus*
7	Indian Pond Heron	*Ardeola grayii*
8	Little Egret	*Egretta garzetta*
9	Little Cormorant	*Microcarbo niger*
10	Black Kite	*Milvus migrans*
11	Brahminy Kite	*Haliastur indus*
12	Crested Serpent Eagle	*Spilornis cheela*
13	Red-headed Vulture	*Sarcogyps calvus*
14	Shikra	*Accipiter badius*
15	White-rumped Vulture	*Gyps bengalensis*
16	Common Kestrel	*Falco tinnunculus*
17	Red-wattled Lapwing	*Vanellus indicus*
18	Yellow-wattled Lapwing	*Vanellus malabaricus*
19	Common Sandpiper	*Actitis hypoleucos*
20	Common Pigeon	*Columba livia*
21	Laughing Dove	*Spilopelia senegalensis*
22	Spotted Dove	*Spilopelia chinensis*
23	Plum-headed Parakeet	*Psittacula cyanocephala*
24	Rose-ringed Parakeet	*Psittacula krameri*
25	Asian Koel	*Eudynamys scolopaceus*
26	Common Hawk-Cuckoo	*Hierococcyx varius*

Scrubland Habitat - Segur		
S.No.	**English Name**	**Scientific Name**
27	Jacobin Cuckoo	*Clamator jacobinus*
28	Asian Palm Swift	*Cypsiurus balasiensis*
29	Indian Roller	*Coracias benghalensis*
30	Common Kingfisher	*Alcedo atthis*
31	White-throated Kingfisher	*Halcyon smyrnensis*
32	Blue-bearded Bee-eater	*Nyctyornis athertoni*
33	Blue-tailed Bee-eater	*Merops philippinus*
34	Green Bee-eater	*Merops orientalis*
35	Indian Grey Hornbill	*Ocyceros birostris*
36	Eurasian Hoopoe	*Upupa epops*
37	Brown-headed Barbet	*Megalaima zeylanica*
38	Coppersmith Barbet	*Megalaima haemacephala*
39	White-cheeked Barbet	*Megalaima viridis*
40	Brown-capped Pygmy Woodpecker	*Dendrocopos nanus*
41	Lesser Goldenback	*Dinopium benghalense*
42	Streak-throated Woodpecker	*Picus xanthopygaeus*
43	Indian Pitta	*Pitta brachyura*
44	Common Woodshrike	*Tephrodornis pondicerianus*
45	Common Iora	*Aegithina tiphia*
46	Black-headed Cuckooshrike	*Coracina melanoptera*
47	Small Minivet	*Pericrocotus cinnamomeus*
48	Oriental White-eye	*Zosterops palpebrosus*
49	Bay-backed Shrike	*Lanius vittatus*
50	Brown Shrike	*Lanius cristatus*
51	Long-tailed Shrike	*Lanius schach*
52	Indian Golden Oriole	*Oriolus kundoo*
53	Ashy Drongo	*Dicrurus leucophaeus*
54	Black Drongo	*Dicrurus macrocercus*
55	White-bellied Drongo	*Dicrurus caerulescens*
56	White-throated Fantail	*Rhipidura albicollis*
57	Asian Paradise Flycatcher	*Terpsiphone paradisi*
58	House Crow	*Corvus splendens*
59	Large-billed Crow	*Corvus macrorhynchos*
60	Rufous Treepie	*Dendrocitta vagabunda*
61	Great Tit	*Parus major*
62	Ashy-crowned Sparrow-Lark	*Eremopterix griseus*
63	Jerdon's Bush Lark	*Mirafra affinis*
64	Red-vented Bulbul	*Pycnonotus cafer*
65	Red-whiskered Bulbul	*Pycnonotus jocosus*

Scrubland Habitat - Segur		
S.No.	**English Name**	**Scientific Name**
66	White-browed Bulbul	*Pycnonotus luteolus*
67	Red-rumped Swallow	*Cecropis daurica*
68	Blyth's Reed Warbler	*Acrocephalus dumetorum*
69	Clamorous Reed Warbler	*Acrocephalus stentoreus*
70	Ashy Prinia	*Prinia socialis*
71	Common Tailorbird	*Orthotomus sutorius*
72	Jungle Prinia	*Prinia sylvatica*
73	Plain Prinia	*Prinia inornata*
74	Lesser Whitethroat	*Sylvia curruca*
75	Brahminy Starling	*Sturnia pagodarum*
76	Common Myna	*Acridotheres tristis*
77	Asian Brown Flycatcher	*Muscicapa dauurica*
78	Brown-breasted Flycatcher	*Muscicapa muttui*
79	Indian Robin	*Saxicoloides fulicatus*
80	Oriental Magpie-Robin	*Copsychus saularis*
81	Pied Bush Chat	*Saxicola caprata*
82	Stonechat	*Saxicola* sp.
83	Crimson-backed Sunbird	*Leptocoma minima*
84	Loten's Sunbird	*Cinnyris lotenius*
85	Purple Sunbird	*Cinnyris asiaticus*
86	Purple-rumped Sunbird	*Leptocoma zeylonica*
87	House Sparrow	*Passer domesticus*
88	Yellow-throated Sparrow	*Gymnoris xanthocollis*
89	Indian Silverbill	*Euodice malabarica*
90	Scaly-breasted Munia	*Lonchura punctulata*
91	White-rumped Munia	*Lonchura striata*
92	Grey Wagtail	*Motacilla cinerea*
93	Paddyfield Pipit	*Anthus rufulus*
94	White-browed Wagtail	*Motacilla maderaspatensis*

Scrubland Habitat - Singara		
S.No.	**English Name**	**Scientific Name**
1	Grey Francolin	*Francolinus pondicerianus*
2	Grey Junglefowl	*Gallus sonneratii*
3	Indian Peafowl	*Pavo cristatus*
4	Jungle Bush Quail	*Perdicula asiatica*
5	Woolly-necked Stork	*Ciconia episcopus*
6	Indian Pond Heron	*Ardeola grayii*
7	Little Egret	*Egretta garzetta*

Scrubland Habitat - Singara		
S.No.	**English Name**	**Scientific Name**
8	Little Cormorant	*Microcarbo niger*
9	Besra	*Accipiter virgatus*
10	Black Eagle	*Ictinaetus malayensis*
11	Black Kite	*Milvus migrans*
12	Brahminy Kite	*Haliastur indus*
13	Crested Serpent Eagle	*Spilornis cheela*
14	Red-headed Vulture	*Sarcogyps calvus*
15	Shikra	*Accipiter badius*
16	White-rumped Vulture	*Gyps bengalensis*
17	Common Kestrel	*Falco tinnunculus*
18	Red-wattled Lapwing	*Vanellus indicus*
19	Common Sandpiper	*Actitis hypoleucos*
20	Common Pigeon	*Columba livia*
21	Laughing Dove	*Spilopelia senegalensis*
22	Spotted Dove	*Spilopelia chinensis*
23	Plum-headed Parakeet	*Psittacula cyanocephala*
24	Rose-ringed Parakeet	*Psittacula krameri*
25	Asian Koel	*Eudynamys scolopaceus*
26	Common Hawk-Cuckoo	*Hierococcyx varius*
27	Jacobin Cuckoo	*Clamator jacobinus*
28	Asian Palm Swift	*Cypsiurus balasiensis*
29	Indian Roller	*Coracias benghalensis*
30	Common Kingfisher	*Alcedo atthis*
31	White-throated Kingfisher	*Halcyon smyrnensis*
32	Blue-bearded Bee-eater	*Nyctyornis athertoni*
33	Blue-tailed Bee-eater	*Merops philippinus*
34	Green Bee-eater	*Merops orientalis*
35	Indian Grey Hornbill	*Ocyceros birostris*
36	Eurasian Hoopoe	*Upupa epops*
37	Brown-headed Barbet	*Megalaima zeylanica*
38	Coppersmith Barbet	*Megalaima haemacephala*
39	White-cheeked Barbet	*Megalaima viridis*
40	Brown-capped Pygmy Woodpecker	*Dendrocopos nanus*
41	Lesser Goldenback	*Dinopium benghalense*
42	Streak-throated Woodpecker	*Picus xanthopygaeus*
43	White-naped Woodpecker	*Chrysocolaptes festivus*
44	Common Woodshrike	*Tephrodornis pondicerianus*
45	Common Iora	*Aegithina tiphia*
46	Black-headed Cuckooshrike	*Coracina melanoptera*

Scrubland Habitat - Singara		
S.No.	**English Name**	**Scientific Name**
47	Large Cuckooshrike	*Coracina macei*
48	Small Minivet	*Pericrocotus cinnamomeus*
49	Oriental White-eye	*Zosterops palpebrosus*
50	Bay-backed Shrike	*Lanius vittatus*
51	Long-tailed Shrike	*Lanius schach*
52	Indian Golden Oriole	*Oriolus kundoo*
53	Ashy Drongo	*Dicrurus leucophaeus*
54	Black Drongo	*Dicrurus macrocercus*
55	White-bellied Drongo	*Dicrurus caerulescens*
56	White-throated Fantail	*Rhipidura albicollis*
57	Asian Paradise Flycatcher	*Terpsiphone paradisi*
58	House Crow	*Corvus splendens*
59	Large-billed Crow	*Corvus macrorhynchos*
60	Rufous Treepie	*Dendrocitta vagabunda*
61	Great Tit	*Parus major*
62	Ashy-crowned Sparrow-Lark	*Eremopterix griseus*
63	Jerdon's Bush Lark	*Mirafra affinis*
64	Red-vented Bulbul	*Pycnonotus cafer*
65	Red-whiskered Bulbul	*Pycnonotus jocosus*
66	White-browed Bulbul	*Pycnonotus luteolus*
67	Red-rumped Swallow	*Cecropis daurica*
68	Blyth's Reed Warbler	*Acrocephalus dumetorum*
69	Clamorous Reed Warbler	*Acrocephalus stentoreus*
70	Ashy Prinia	*Prinia socialis*
71	Common Tailorbird	*Orthotomus sutorius*
72	Jungle Prinia	*Prinia sylvatica*
73	Plain Prinia	*Prinia inornata*
74	Brahminy Starling	*Sturnia pagodarum*
75	Common Myna	*Acridotheres tristis*
76	Asian Brown Flycatcher	*Muscicapa dauurica*
77	Brown-breasted Flycatcher	*Muscicapa muttui*
78	Indian Robin	*Saxicoloides fulicatus*
79	Oriental Magpie-Robin	*Copsychus saularis*
80	Pied Bush Chat	*Saxicola caprata*
81	Crimson-backed Sunbird	*Leptocoma minima*
82	Loten's Sunbird	*Cinnyris lotenius*
83	Purple Sunbird	*Cinnyris asiaticus*
84	Purple-rumped Sunbird	*Leptocoma zeylonica*
85	House Sparrow	*Passer domesticus*

Scrubland Habitat - Singara		
S.No.	**English Name**	**Scientific Name**
86	Yellow-throated Sparrow	*Gymnoris xanthocollis*
87	Indian Silverbill	*Euodice malabarica*
88	Scaly-breasted Munia	*Lonchura punctulata*
89	White-rumped Munia	*Lonchura striata*
90	Grey Wagtail	*Motacilla cinerea*
91	Paddyfield Pipit	*Anthus rufulus*
92	White-browed Wagtail	*Motacilla maderaspatensis*

Montane Habitat - Pykara (Glenmorgen)		
S.No.	**English Name**	**Scientific Name**
1	Common Sandpiper	*Actitis hypoleucos*
2	Spotted Dove	*Spilopelia chinensis*
3	Common Kingfisher	*Alcedo atthis*
4	Stork-billed Kingfisher	*Pelargopsis capensis*
5	White-throated Kingfisher	*Halcyon smyrnensis*
6	Eurasian Hoopoe	*Upupa epops*
7	Coppersmith Barbet	*Megalaima haemacephala*
8	White-cheeked Barbet	*Megalaima viridis*
9	Lesser Yellownape	*Picus chlorolophus*
10	Streak-throated Woodpecker	*Picus xanthopygaeus*
11	White-naped Woodpecker	*Chrysocolaptes festivus*
12	Bar-winged Flycatcher-shrike	*Hemipus picatus*
13	Common Iora	*Aegithina tiphia*
14	Oriental White-eye	*Zosterops palpebrosus*
15	Small Minivet	*Pericrocotus cinnamomeus*
16	Brown Shrike	*Lanius cristatus*
17	Indian Golden Oriole	*Oriolus kundoo*
18	Black Drongo	*Dicrurus macrocercus*
19	Bronzed Drongo	*Dicrurus aeneus*
20	Greater Racket-tailed Drongo	*Dicrurus paradiseus*
21	Asian Paradise Flycatcher	*Terpsiphone paradisi*
22	House Crow	*Corvus splendens*
23	Large-billed Crow	*Corvus macrorhynchos*
24	Malabar Lark	*Galerida malabarica*
25	Black Bulbul	*Hypsipetes leucocephalus*
26	Red-vented Bulbul	*Pycnonotus cafer*
27	Red-whiskered Bulbul	*Pycnonotus jocosus*
28	White-browed Bulbul	*Pycnonotus luteolus*
29	Red-rumped Swallow	*Cecropis daurica*

Montane Habitat - Pykara (Glenmorgen)		
S.No.	**English Name**	**Scientific Name**
30	Greenish Warbler	*Phylloscopus* sp.
31	Common Tailorbird	*Orthotomus sutorius*
32	Asian Fairy-bluebird	*Irena puella*
33	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*
34	Velvet-fronted Nuthatch	*Sitta frontalis*
35	Brahminy Starling	*Sturnia pagodarum*
36	Common Myna	*Acridotheres tristis*
37	Jungle Myna	*Acridotheres fuscus*
38	Indian Blackbird	*Turdus simillimus*
39	Malabar Whistling Thrush	*Myophonus horsfieldii*
40	Pied Bush Chat	*Saxicola caprata*
41	Crimson-backed Sunbird	*Leptocoma minima*
42	Purple Sunbird	*Cinnyris asiaticus*
43	Purple-rumped Sunbird	*Leptocoma zeylonica*
44	House Sparrow	*Passer domesticus*
45	Nilgiri Pipit	*Anthus nilghiriensis*
46	White-browed Wagtail	*Motacilla maderaspatensis*

Montane Habitat - Pykara (Kulimundh)		
S.No.	**English Name**	**Scientific Name**
1	Spotted Dove	*Spilopelia chinensis*
2	White-throated Kingfisher	*Halcyon smyrnensis*
3	Eurasian Hoopoe	*Upupa epops*
4	Coppersmith Barbet	*Megalaima haemacephala*
5	White-cheeked Barbet	*Megalaima viridis*
6	Bar-winged Flycatcher-shrike	*Hemipus picatus*
7	Common Iora	*Aegithina tiphia*
8	Black-headed Cuckooshrike	*Coracina melanoptera*
9	Large Cuckooshrike	*Coracina macei*
10	Small Minivet	*Pericrocotus cinnamomeus*
11	Oriental White-eye	*Zosterops palpebrosus*
12	Brown Shrike	*Lanius cristatus*
13	Indian Golden Oriole	*Oriolus kundoo*
14	Black Drongo	*Dicrurus macrocercus*
15	White-bellied Drongo	*Dicrurus caerulescens*
16	Asian Paradise Flycatcher	*Terpsiphone paradisi*
17	House Crow	*Corvus splendens*
18	Large-billed Crow	*Corvus macrorhynchos*
19	Malabar Lark	*Galerida malabarica*

Montane Habitat - Pykara (Kulimundh)		
S.No.	**English Name**	**Scientific Name**
20	Red-vented Bulbul	*Pycnonotus cafer*
21	Red-whiskered Bulbul	*Pycnonotus jocosus*
22	White-browed Bulbul	*Pycnonotus luteolus*
23	Greenish Warbler	*Phylloscopus* sp.
24	Common Tailorbird	*Orthotomus sutorius*
25	Jungle Babbler	*Turdoides striata*
26	Asian Fairy-bluebird	*Irena puella*
27	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*
28	Brahminy Starling	*Sturnia pagodarum*
29	Common Myna	*Acridotheres tristis*
30	Indian Blackbird	*Turdus simillimus*
31	Malabar Whistling Thrush	*Myophonus horsfieldii*
32	Asian Brown Flycatcher	*Muscicapa dauurica*
33	Brown-breasted Flycatcher	*Muscicapa muttui*
34	Nilgiri Flycatcher	*Eumyias albicaudatus*
35	Pied Bush Chat	*Saxicola caprata*
36	Verditer Flycatcher	*Eumyias thalassinus*
37	Jerdon's Leafbird	*Chloropsis jerdoni*
38	Crimson-backed Sunbird	*Leptocoma minima*
39	Purple-rumped Sunbird	*Leptocoma zeylonica*
40	House Sparrow	*Passer domesticus*
41	Nilgiri Pipit	*Anthus nilghiriensis*
42	White-browed Wagtail	*Motacilla maderaspatensis*
43	White-throated Kingfisher	*Halcyon smyrnensis*
44	Streak-throated Woodpecker	*Picus xanthopygaeus*
45	Jungle Myna	*Acridotheres fuscus*
46	Pipit	*Anthus* sp.

Montane Habitat - Naduvattam		
S. No	**English Name**	**Scientific Name**
1	Eurasian Hoopoe	*Upupa epops*
2	Spotted Dove	*Spilopelia chinensis*
3	White-throated Kingfisher	*Halcyon smyrnensis*
4	Common Iora	*Aegithina tiphia*
5	Common Tailorbird	*Orthotomus sutorius*
6	Large-billed Crow	*Corvus macrorhynchos*
7	Black Drongo	*Dicrurus macrocercus*
8	Asian Fairy-bluebird	*Irena puella*
9	Asian Paradise Flycatcher	*Terpsiphone paradisi*

Montane Habitat - Naduvattam		
S. No	**English Name**	**Scientific Name**
10	Nilgiri Pipit	*Anthus nilghiriensis*
11	Pipit	*Anthus* sp.
12	White-browed Wagtail	*Motacilla maderaspatensis*
13	Nilgiri Flycatcher	*Eumyias albicaudatus*
14	Pied Bush Chat	*Saxicola caprata*
15	Verditer Flycatcher	*Eumyias thalassinus*
16	Crimson-backed Sunbird	*Leptocoma minima*
17	Purple-rumped Sunbird	*Leptocoma zeylonica*
18	House Sparrow	*Passer domesticus*
19	Greenish Warbler	*Phylloscopus* sp.
20	Red-vented Bulbul	*Pycnonotus cafer*
21	Red-whiskered Bulbul	*Pycnonotus jocosus*
22	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*
23	Brahminy Starling	*Sturnia pagodarum*
24	Common Myna	*Acridotheres tristis*
25	Indian Blackbird	*Turdus simillimus*
26	Malabar Whistling Thrush	*Myophonus horsfieldii*
27	Coppersmith Barbet	*Megalaima haemacephala*
28	White-cheeked Barbet	*Megalaima viridis*
29	Streak-throated Woodpecker	*Picus xanthopygaeus*

Deciduous Habitat - Masinagudi (Maan Board)		
S.No.	**English Name**	**Scientific Name**
1	Grey Francolin	*Francolinus pondicerianus*
2	Grey Junglefowl	*Gallus sonneratii*
3	Indian Peafowl	*Pavo cristatus*
4	Black Kite	*Milvus migrans*
5	Brahminy Kite	*Haliastur indus*
6	Crested Serpent Eagle	*Spilornis cheela*
7	Shikra	*Accipiter badius*
8	Common Kestrel	*Falco tinnunculus*
9	Red-wattled Lapwing	*Vanellus indicus*
10	Spotted Dove	*Spilopelia chinensis*
11	Rose-ringed Parakeet	*Psittacula krameri*
12	Asian Koel	*Eudynamys scolopaceus*
13	Common Hawk-Cuckoo	*Hierococcyx varius*
14	Jacobin Cuckoo	*Clamator jacobinus*
15	Asian Palm Swift	*Cypsiurus balasiensis*
16	White-throated Kingfisher	*Halcyon smyrnensis*

Deciduous Habitat - Masinagudi (Maan Board)		
S.No.	**English Name**	**Scientific Name**
17	Blue-bearded Bee-eater	*Nyctyornis athertoni*
18	Blue-tailed Bee-eater	*Merops philippinus*
19	Eurasian Hoopoe	*Upupa epops*
20	Coppersmith Barbet	*Megalaima haemacephala*
21	Lesser Goldenback	*Dinopium benghalense*
22	Streak-throated Woodpecker	*Picus xanthopygaeus*
23	Indian Pitta	*Pitta brachyura*
24	Common Woodshrike	*Tephrodornis pondicerianus*
25	Common Iora	*Aegithina tiphia*
26	Black-headed Cuckooshrike	*Coracina melanoptera*
27	Small Minivet	*Pericrocotus cinnamomeus*
28	Bay-backed Shrike	*Lanius vittatus*
29	Indian Golden Oriole	*Oriolus kundoo*
30	Black Drongo	*Dicrurus macrocercus*
31	Asian Paradise Flycatcher	*Terpsiphone paradisi*
32	Large-billed Crow	*Corvus macrorhynchos*
33	Rufous Treepie	*Dendrocitta vagabunda*
34	Great Tit	*Parus major*
35	Red-vented Bulbul	*Pycnonotus cafer*
36	Red-whiskered Bulbul	*Pycnonotus jocosus*
37	White-browed Bulbul	*Pycnonotus luteolus*
38	Red-rumped Swallow	*Cecropis daurica*
39	Blyth's Reed Warbler	*Acrocephalus dumetorum*
40	Clamorous Reed Warbler	*Acrocephalus stentoreus*
41	Ashy Prinia	*Prinia socialis*
42	Common Tailorbird	*Orthotomus sutorius*
43	Jungle Prinia	*Prinia sylvatica*
44	Plain Prinia	*Prinia inornata*
45	Asian Fairy-bluebird	*Irena puella*
46	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*
47	Brahminy Starling	*Sturnia pagodarum*
48	Common Myna	*Acridotheres tristis*
49	Orange-headed Thrush	*Zoothera citrina*
50	Asian Brown Flycatcher	*Muscicapa dauurica*
51	Brown-breasted Flycatcher	*Muscicapa muttui*
52	Oriental Magpie-Robin	*Copsychus saularis*
53	Pied Bush Chat	*Saxicola caprata*
54	Loten's Sunbird	*Cinnyris lotenius*
55	Purple Sunbird	*Cinnyris asiaticus*

Deciduous Habitat - Masinagudi (Maan Board)

S.No.	English Name	Scientific Name
56	Purple-rumped Sunbird	*Leptocoma zeylonica*
57	Paddyfield Pipit	*Anthus rufulus*
58	White-browed Wagtail	*Motacilla maderaspatensis*

Deciduous Habitat - Masinagudi (Periakulam)

S.No.	English Name	Scientific Name
1	Grey Francolin	*Francolinus pondicerianus*
2	Grey Junglefowl	*Gallus sonneratii*
3	Indian Peafowl	*Pavo cristatus*
4	Woolly-necked Stork	*Ciconia episcopus*
5	Indian Pond Heron	*Ardeola grayii*
6	Little Egret	*Egretta garzetta*
7	Little Cormorant	*Microcarbo niger*
8	Black Kite	*Milvus migrans*
9	Brahminy Kite	*Haliastur indus*
10	Crested Serpent Eagle	*Spilornis cheela*
11	Shikra	*Accipiter badius*
12	Common Kestrel	*Falco tinnunculus*
13	Red-wattled Lapwing	*Vanellus indicus*
14	Common Sandpiper	*Actitis hypoleucos*
15	Spotted Dove	*Spilopelia chinensis*
16	Plum-headed Parakeet	*Psittacula cyanocephala*
17	Rose-ringed Parakeet	*Psittacula krameri*
18	Blue-winged Parakeet	*Psittacula columboides*
19	Asian Koel	*Eudynamys scolopaceus*
20	Common Hawk-Cuckoo	*Hierococcyx varius*
21	Jacobin Cuckoo	*Clamator jacobinus*
22	Asian Palm Swift	*Cypsiurus balasiensis*
23	Indian Roller	*Coracias benghalensis*
24	Common Kingfisher	*Alcedo atthis*
25	Pied Kingfisher	*Ceryle rudis*
26	White-throated Kingfisher	*Halcyon smyrnensis*
27	Blue-bearded Bee-eater	*Nyctyornis athertoni*
28	Blue-tailed Bee-eater	*Merops philippinus*
29	Green Bee-eater	*Merops orientalis*
30	Indian Grey Hornbill	*Ocyceros birostris*
31	Eurasian Hoopoe	*Upupa epops*
32	Coppersmith Barbet	*Megalaima haemacephala*
33	Brown-capped Pygmy	*Dendrocopos nanus*

Deciduous Habitat - Masinagudi (Periakulam)

S.No.	English Name	Scientific Name
	Woodpecker	
34	Lesser Goldenback	*Dinopium benghalense*
35	Streak-throated Woodpecker	*Picus xanthopygaeus*
36	Indian Pitta	*Pitta brachyura*
37	Common Woodshrike	*Tephrodornis pondicerianus*
38	Common Iora	*Aegithina tiphia*
39	Black-headed Cuckooshrike	*Coracina melanoptera*
40	Small Minivet	*Pericrocotus cinnamomeus*
41	Bay-backed Shrike	*Lanius vittatus*
42	Indian Golden Oriole	*Oriolus kundoo*
43	Ashy Drongo	*Dicrurus leucophaeus*
44	Black Drongo	*Dicrurus macrocercus*
45	Bronzed Drongo	*Dicrurus aeneus*
46	White-bellied Drongo	*Dicrurus caerulescens*
47	Asian Paradise Flycatcher	*Terpsiphone paradisi*
48	House Crow	*Corvus splendens*
49	Large-billed Crow	*Corvus macrorhynchos*
50	Rufous Treepie	*Dendrocitta vagabunda*
51	Great Tit	*Parus major*
52	Jerdon's Bush Lark	*Mirafra affinis*
53	Red-vented Bulbul	*Pycnonotus cafer*
54	Red-whiskered Bulbul	*Pycnonotus jocosus*
55	White-browed Bulbul	*Pycnonotus luteolus*
56	Barn Swallow	*Hirundo rustica*
57	Red-rumped Swallow	*Cecropis daurica*
58	Blyth's Reed Warbler	*Acrocephalus dumetorum*
59	Clamorous Reed Warbler	*Acrocephalus stentoreus*
60	Ashy Prinia	*Prinia socialis*
61	Common Tailorbird	*Orthotomus sutorius*
62	Jungle Babbler	*Turdoides striata*
63	Asian Fairy-bluebird	*Irena puella*
64	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*
65	Velvet-fronted Nuthatch	*Sitta frontalis*
66	Brahminy Starling	*Sturnia pagodarum*
67	Common Myna	*Acridotheres tristis*
68	Asian Brown Flycatcher	*Muscicapa dauurica*
69	Oriental Magpie-Robin	*Copsychus saularis*
70	Pied Bush Chat	*Saxicola caprata*
71	Crimson-backed Sunbird	*Leptocoma minima*

Deciduous Habitat - Masinagudi (Periakulam)		
S.No.	**English Name**	**Scientific Name**
72	Loten's Sunbird	*Cinnyris lotenius*
73	Purple Sunbird	*Cinnyris asiaticus*
74	Purple-rumped Sunbird	*Leptocoma zeylonica*
75	House Sparrow	*Passer domesticus*
76	Scaly-breasted Munia	*Lonchura punctulata*
77	Grey Wagtail	*Motacilla cinerea*
78	Paddyfield Pipit	*Anthus rufulus*
79	White-browed Wagtail	*Motacilla maderaspatensis*

Deciduous Habitat - Teppakadu		
S.No.	**English Name**	**Scientific Name**
1	Grey Francolin	*Francolinus pondicerianus*
2	Grey Junglefowl	*Gallus sonneratii*
3	Indian Peafowl	*Pavo cristatus*
4	Indian Pond Heron	*Ardeola grayii*
5	Little Egret	*Egretta garzetta*
6	Little Cormorant	*Microcarbo niger*
7	Black Eagle	*Ictinaetus malayensis*
8	Black Kite	*Milvus migrans*
9	Brahminy Kite	*Haliastur indus*
10	Crested Serpent Eagle	*Spilornis cheela*
11	Shikra	*Accipiter badius*
12	Common Kestrel	*Falco tinnunculus*
13	Red-wattled Lapwing	*Vanellus indicus*
14	Common Sandpiper	*Actitis hypoleucos*
15	Spotted Dove	*Spilopelia chinensis*
16	Plum-headed Parakeet	*Psittacula cyanocephala*
17	Rose-ringed Parakeet	*Psittacula krameri*
18	Blue-winged Parakeet	*Psittacula columboides*
19	Asian Koel	*Eudynamys scolopaceus*
20	Common Hawk-Cuckoo	*Hierococcyx varius*
21	Jacobin Cuckoo	*Clamator jacobinus*
22	Asian Palm Swift	*Cypsiurus balasiensis*
23	Indian Roller	*Coracias benghalensis*
24	Common Kingfisher	*Alcedo atthis*
25	Pied Kingfisher	*Ceryle rudis*
26	White-throated Kingfisher	*Halcyon smyrnensis*
27	Blue-tailed Bee-eater	*Merops philippinus*
28	Green Bee-eater	*Merops orientalis*

Deciduous Habitat - Teppakadu		
S.No.	**English Name**	**Scientific Name**
29	Indian Grey Hornbill	*Ocyceros birostris*
30	Eurasian Hoopoe	*Upupa epops*
31	Coppersmith Barbet	*Megalaima haemacephala*
32	Brown-capped Pygmy Woodpecker	*Dendrocopos nanus*
33	Lesser Goldenback	*Dinopium benghalense*
34	Streak-throated Woodpecker	*Picus xanthopygaeus*
35	Common Woodshrike	*Tephrodornis pondicerianus*
36	Common Iora	*Aegithina tiphia*
37	Black-headed Cuckooshrike	*Coracina melanoptera*
38	Small Minivet	*Pericrocotus cinnamomeus*
39	Bay-backed Shrike	*Lanius vittatus*
40	Indian Golden Oriole	*Oriolus kundoo*
41	Ashy Drongo	*Dicrurus leucophaeus*
42	Black Drongo	*Dicrurus macrocercus*
43	Bronzed Drongo	*Dicrurus aeneus*
44	White-bellied Drongo	*Dicrurus caerulescens*
45	Asian Paradise Flycatcher	*Terpsiphone paradisi*
46	House Crow	*Corvus splendens*
47	Large-billed Crow	*Corvus macrorhynchos*
48	Rufous Treepie	*Dendrocitta vagabunda*
49	Great Tit	*Parus major*
50	Jerdon's Bush Lark	*Mirafra affinis*
51	Red-vented Bulbul	*Pycnonotus cafer*
52	Red-whiskered Bulbul	*Pycnonotus jocosus*
53	White-browed Bulbul	*Pycnonotus luteolus*
54	Barn Swallow	*Hirundo rustica*
55	Red-rumped Swallow	*Cecropis daurica*
56	Blyth's Reed Warbler	*Acrocephalus dumetorum*
57	Clamorous Reed Warbler	*Acrocephalus stentoreus*
58	Ashy Prinia	*Prinia socialis*
59	Common Tailorbird	*Orthotomus sutorius*
60	Plain Prinia	*Prinia inornata*
61	Asian Fairy-bluebird	*Irena puella*
62	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*
63	Velvet-fronted Nuthatch	*Sitta frontalis*
64	Brahminy Starling	*Sturnia pagodarum*
65	Common Myna	*Acridotheres tristis*
66	Asian Brown Flycatcher	*Muscicapa dauurica*
67	Oriental Magpie-Robin	*Copsychus saularis*

Deciduous Habitat - Teppakadu		
S.No.	**English Name**	**Scientific Name**
68	Pied Bush Chat	*Saxicola caprata*
69	Crimson-backed Sunbird	*Leptocoma minima*
70	Loten's Sunbird	*Cinnyris lotenius*
71	Purple Sunbird	*Cinnyris asiaticus*
72	Purple-rumped Sunbird	*Leptocoma zeylonica*
73	House Sparrow	*Passer domesticus*
74	Scaly-breasted Munia	*Lonchura punctulata*
75	Grey Wagtail	*Motacilla cinerea*
76	Paddyfield Pipit	*Anthus rufulus*
77	White-browed Wagtail	*Motacilla maderaspatensis*

Deciduous Habitat - Kargudi		
S.No.	**English Name**	**Scientific Name**
1	Grey Francolin	*Francolinus pondicerianus*
2	Grey Junglefowl	*Gallus sonneratii*
3	Indian Peafowl	*Pavo cristatus*
4	Indian Pond Heron	*Ardeola grayii*
5	Little Egret	*Egretta garzetta*
6	Little Cormorant	*Microcarbo niger*
7	Black Eagle	*Ictinaetus malayensis*
8	Black Kite	*Milvus migrans*
9	Brahminy Kite	*Haliastur indus*
10	Crested Serpent Eagle	*Spilornis cheela*
11	Shikra	*Accipiter badius*
12	Common Kestrel	*Falco tinnunculus*
13	Red-wattled Lapwing	*Vanellus indicus*
14	Spotted Dove	*Spilopelia chinensis*
15	Plum-headed Parakeet	*Psittacula cyanocephala*
16	Rose-ringed Parakeet	*Psittacula krameri*
17	Blue-winged Parakeet	*Psittacula columboides*
18	Asian Koel	*Eudynamys scolopaceus*
19	Common Hawk-Cuckoo	*Hierococcyx varius*
20	Jacobin Cuckoo	*Clamator jacobinus*
21	Asian Palm Swift	*Cypsiurus balasiensis*
22	Indian Roller	*Coracias benghalensis*
23	Common Kingfisher	*Alcedo atthis*
24	White-throated Kingfisher	*Halcyon smyrnensis*
25	Blue-bearded Bee-eater	*Nyctyornis athertoni*
26	Blue-tailed Bee-eater	*Merops philippinus*

Deciduous Habitat - Kargudi		
S.No.	**English Name**	**Scientific Name**
27	Green Bee-eater	*Merops orientalis*
28	Indian Grey Hornbill	*Ocyceros birostris*
29	Eurasian Hoopoe	*Upupa epops*
30	Coppersmith Barbet	*Megalaima haemacephala*
31	Brown-capped Pygmy Woodpecker	*Dendrocopos nanus*
32	Lesser Goldenback	*Dinopium benghalense*
33	Streak-throated Woodpecker	*Picus xanthopygaeus*
34	White-naped Woodpecker	*Chrysocolaptes festivus*
35	Indian Pitta	*Pitta brachyura*
36	Common Woodshrike	*Tephrodornis pondicerianus*
37	Common Iora	*Aegithina tiphia*
38	Black-headed Cuckooshrike	*Coracina melanoptera*
39	Small Minivet	*Pericrocotus cinnamomeus*
40	Bay-backed Shrike	*Lanius vittatus*
41	Indian Golden Oriole	*Oriolus kundoo*
42	Ashy Drongo	*Dicrurus leucophaeus*
43	Black Drongo	*Dicrurus macrocercus*
44	Bronzed Drongo	*Dicrurus aeneus*
45	White-bellied Drongo	*Dicrurus caerulescens*
46	Asian Paradise Flycatcher	*Terpsiphone paradisi*
47	House Crow	*Corvus splendens*
48	Large-billed Crow	*Corvus macrorhynchos*
49	Rufous Treepie	*Dendrocitta vagabunda*
50	Great Tit	*Parus major*
51	Jerdon's Bush Lark	*Mirafra affinis*
52	Red-vented Bulbul	*Pycnonotus cafer*
53	Red-whiskered Bulbul	*Pycnonotus jocosus*
54	White-browed Bulbul	*Pycnonotus luteolus*
55	Red-rumped Swallow	*Cecropis daurica*
56	Blyth's Reed Warbler	*Acrocephalus dumetorum*
57	Clamorous Reed Warbler	*Acrocephalus stentoreus*
58	Ashy Prinia	*Prinia socialis*
59	Common Tailorbird	*Orthotomus sutorius*
60	Jungle Prinia	*Prinia sylvatica*
61	Jungle Babbler	*Turdoides striata*
62	Asian Fairy-bluebird	*Irena puella*
63	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*
64	Brahminy Starling	*Sturnia pagodarum*
65	Common Myna	*Acridotheres tristis*

Deciduous Habitat - Kargudi

S.No.	English Name	Scientific Name
66	Orange-headed Thrush	*Zoothera citrina*
67	Asian Brown Flycatcher	*Muscicapa dauurica*
68	Brown-breasted Flycatcher	*Muscicapa muttui*
69	Oriental Magpie-Robin	*Copsychus saularis*
70	Pied Bush Chat	*Saxicola caprata*
71	Crimson-backed Sunbird	*Leptocoma minima*
72	Loten's Sunbird	*Cinnyris lotenius*
73	Purple Sunbird	*Cinnyris asiaticus*
74	Purple-rumped Sunbird	*Leptocoma zeylonica*
75	House Sparrow	*Passer domesticus*
76	Yellow-throated Sparrow	*Gymnoris xanthocollis*
77	Scaly-breasted Munia	*Lonchura punctulata*
78	Grey Wagtail	*Motacilla cinerea*
79	Paddyfield Pipit	*Anthus rufulus*
80	White-browed Wagtail	*Motacilla maderaspatensis*

Opuntia vulgaris Mill.

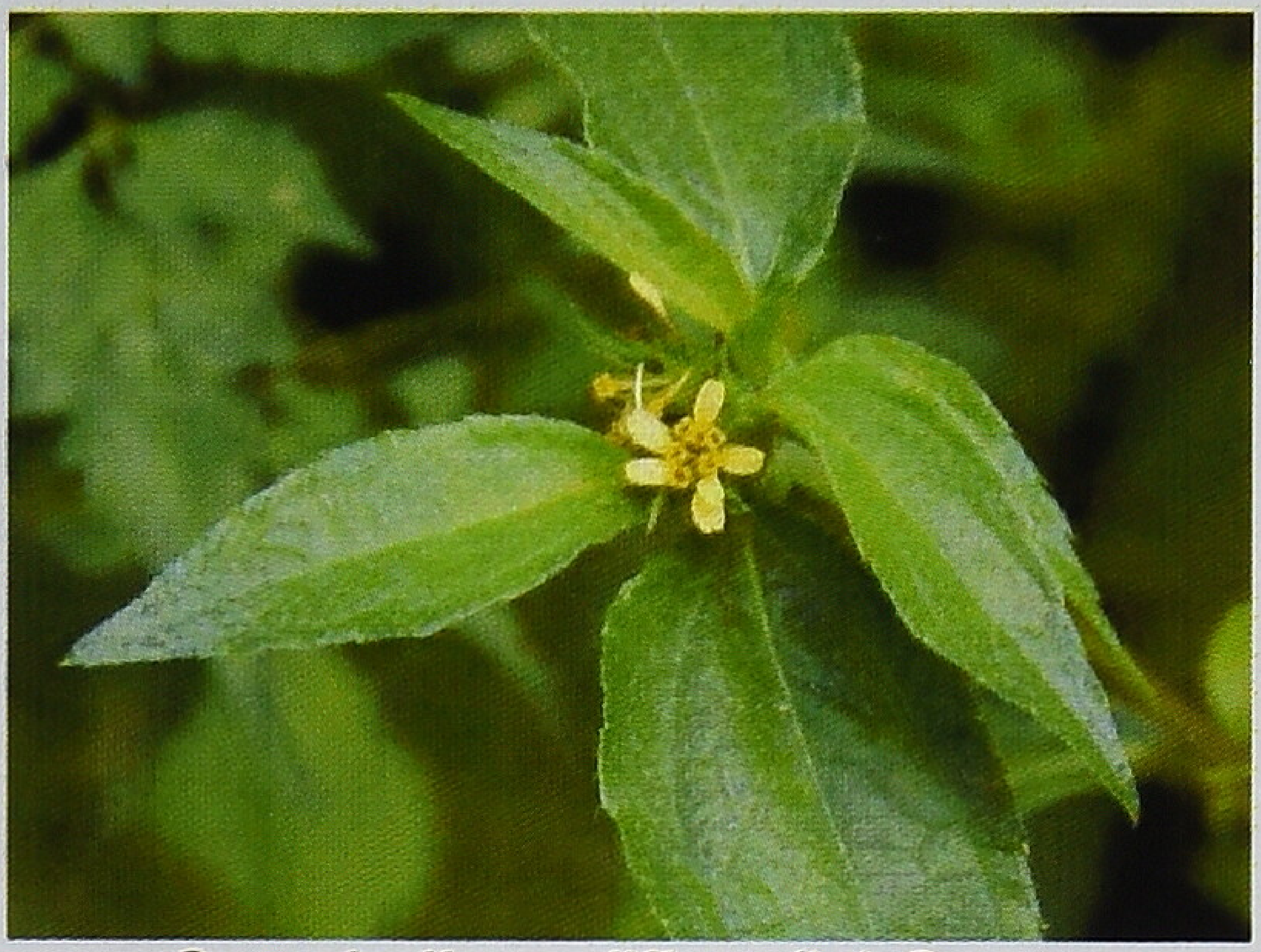
Sida cordifolia L.

Opuntia dillenii (Ker Gawl.) Haw

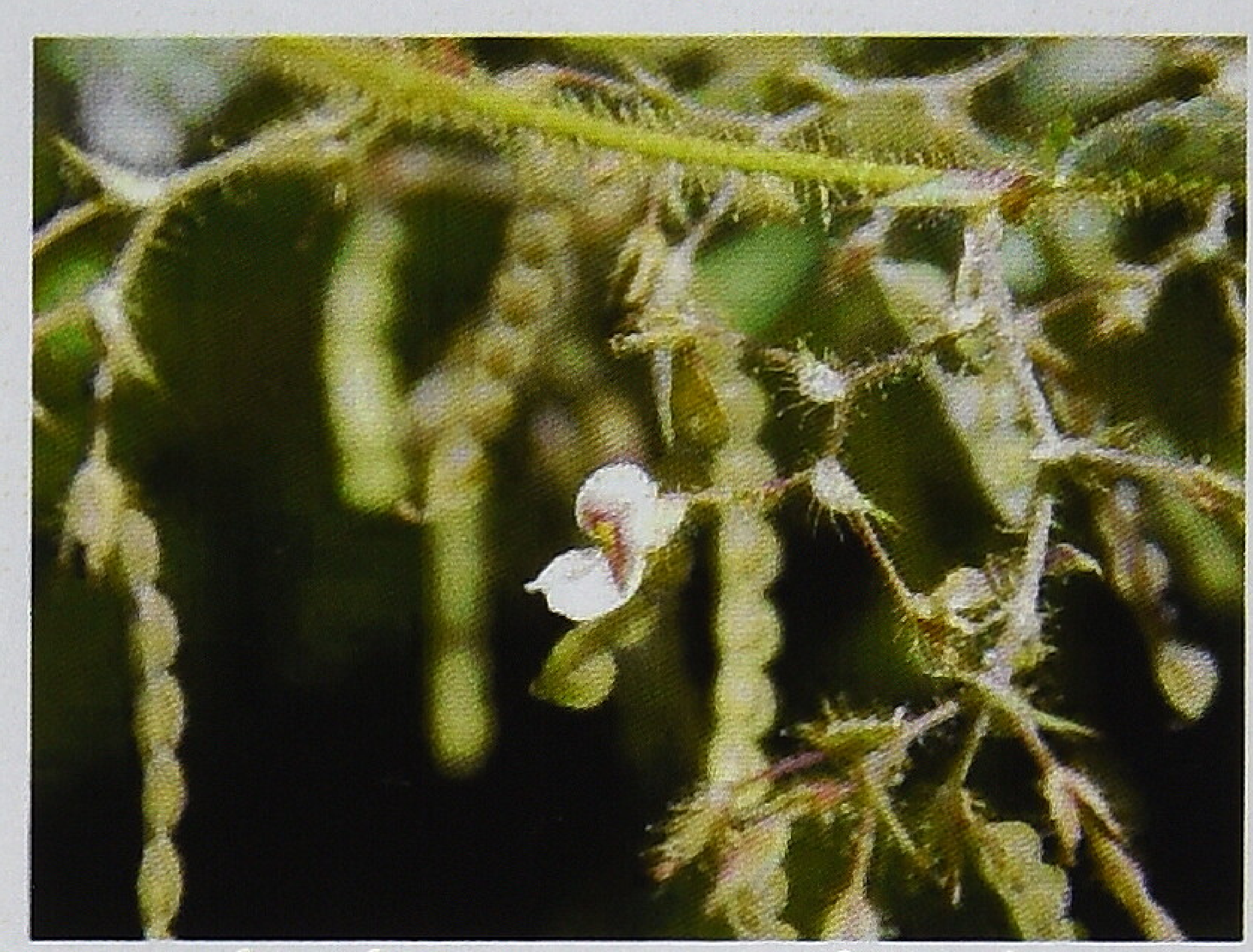
Vanda tessellata (Roxb.) Hook ex. G. Don

Setaria verticillata (L.) P. Beauv

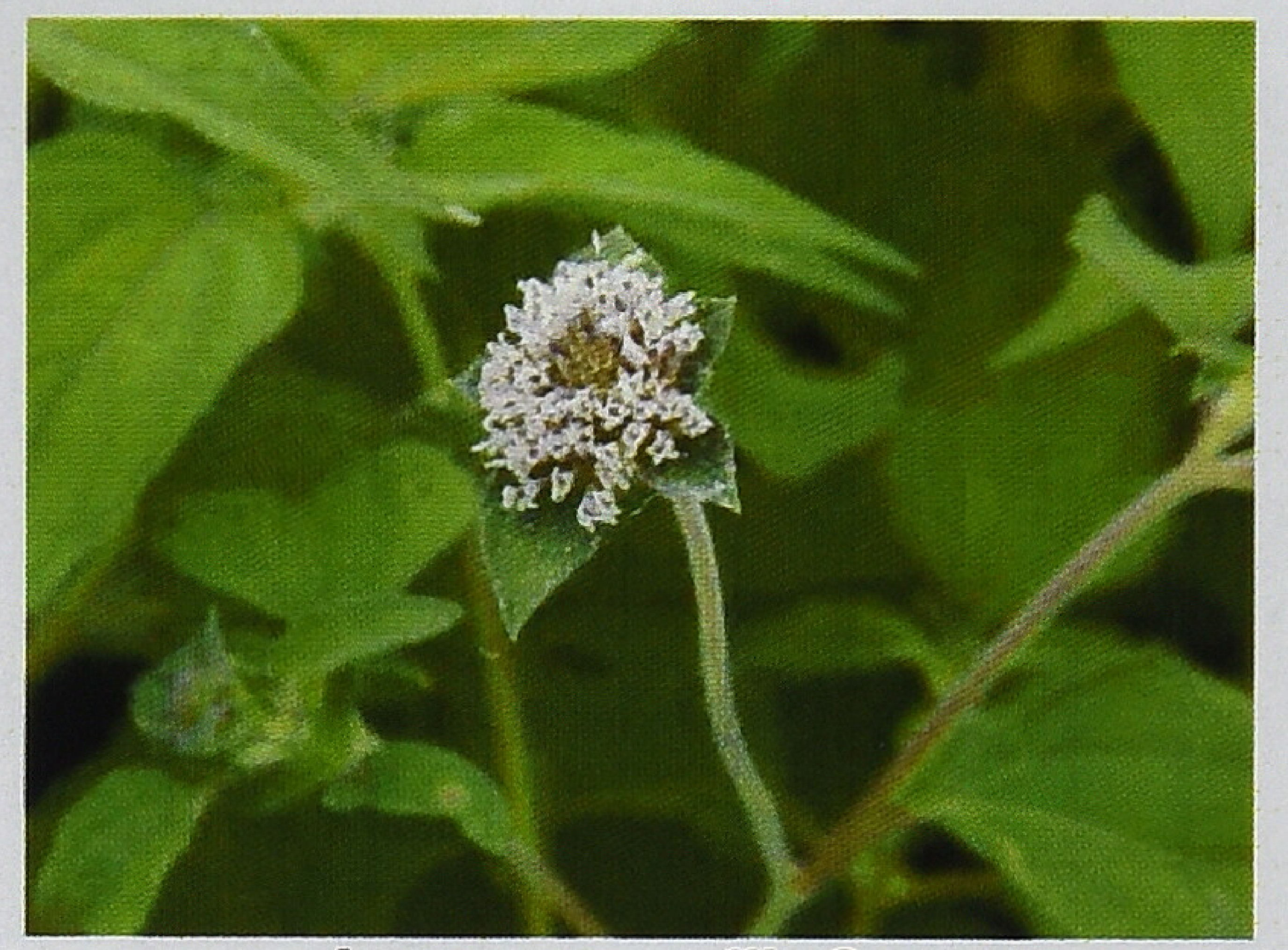
Dactyloctenium aegyptium (L.) Willd.



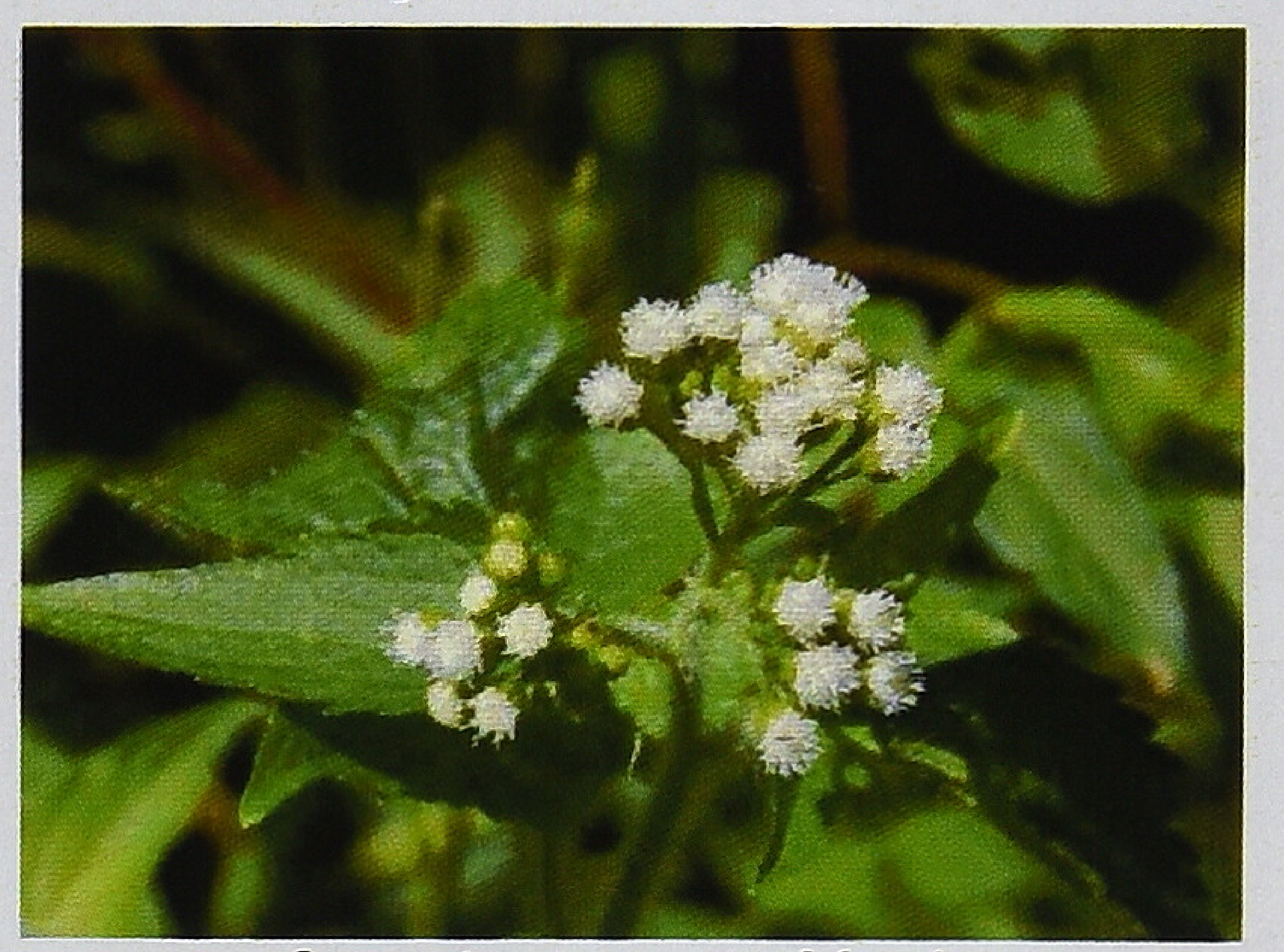
Synedrella nodiflora (L.) Gaertn



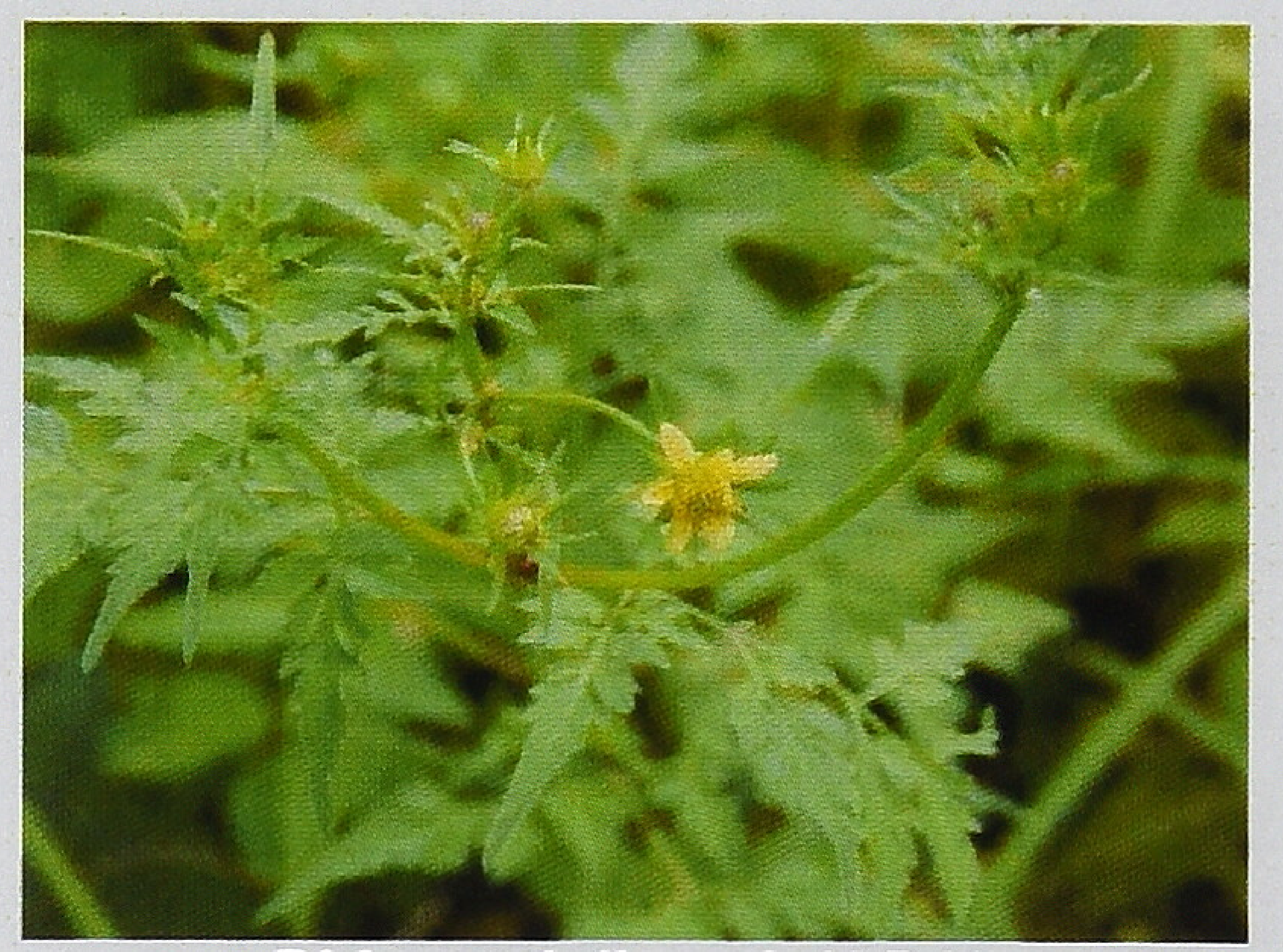
Aeschynomene americana L.



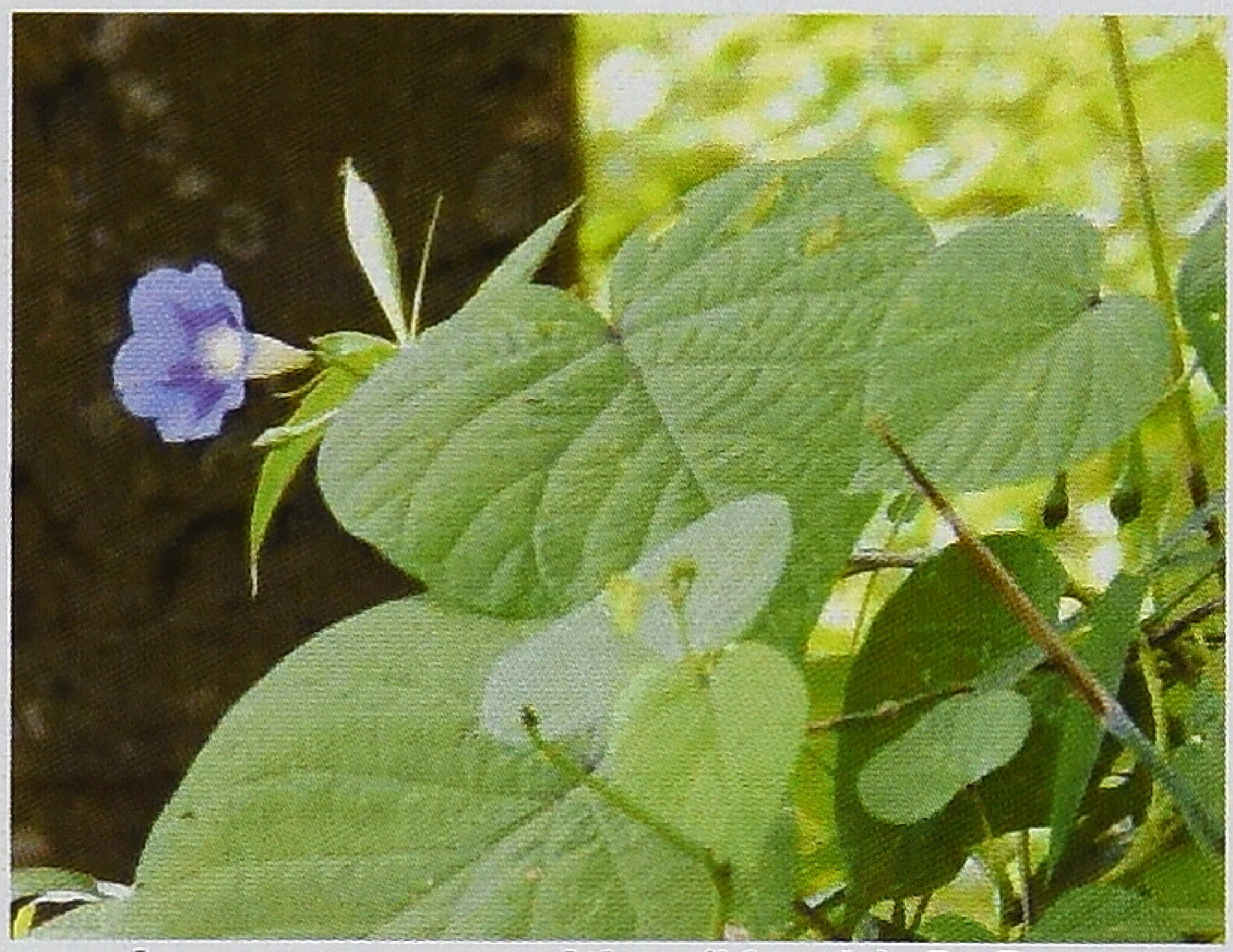
Lagascea mollis Cav.



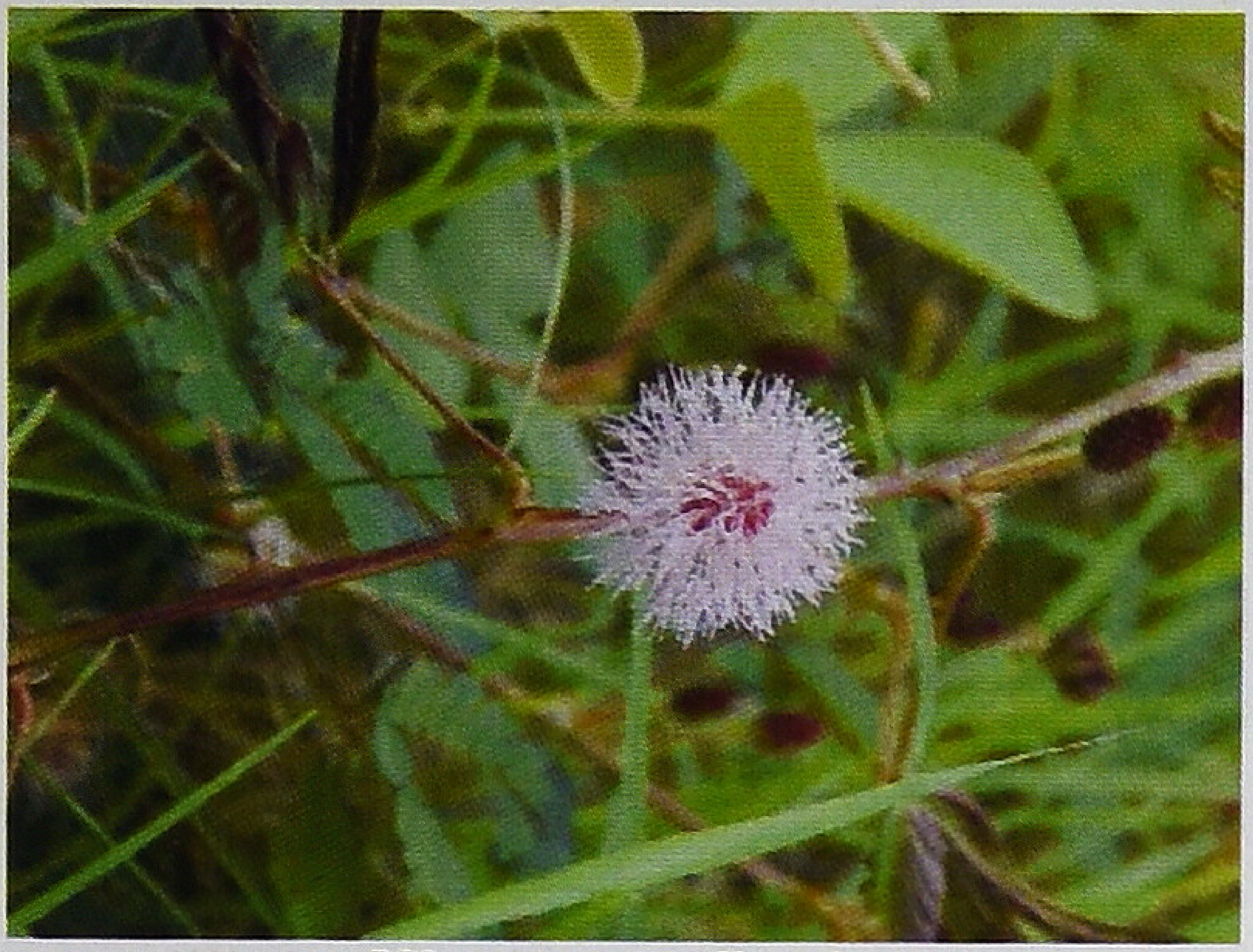
Ageratum conyzoides L.



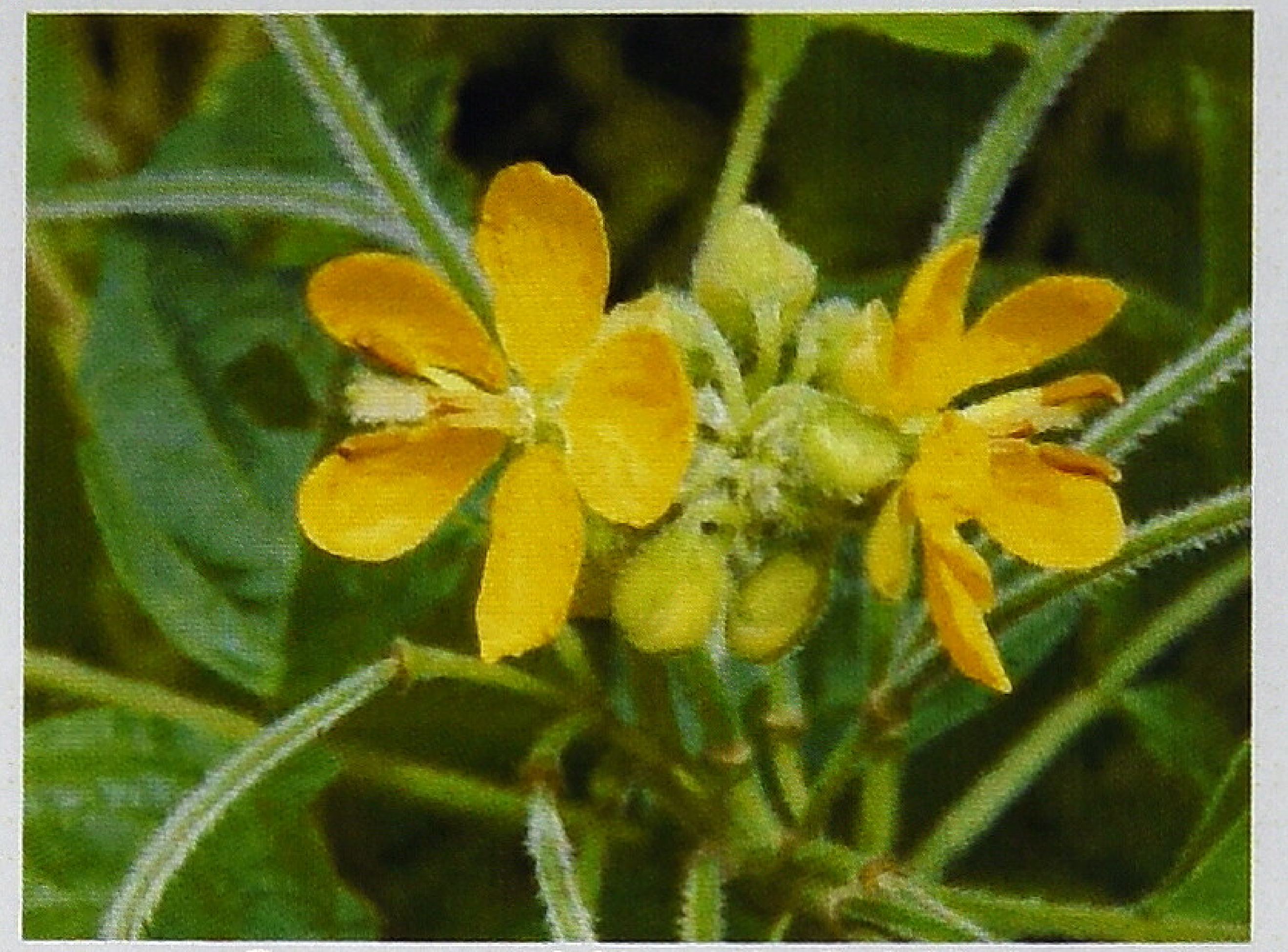
Bidens triplinervia H.B.K.



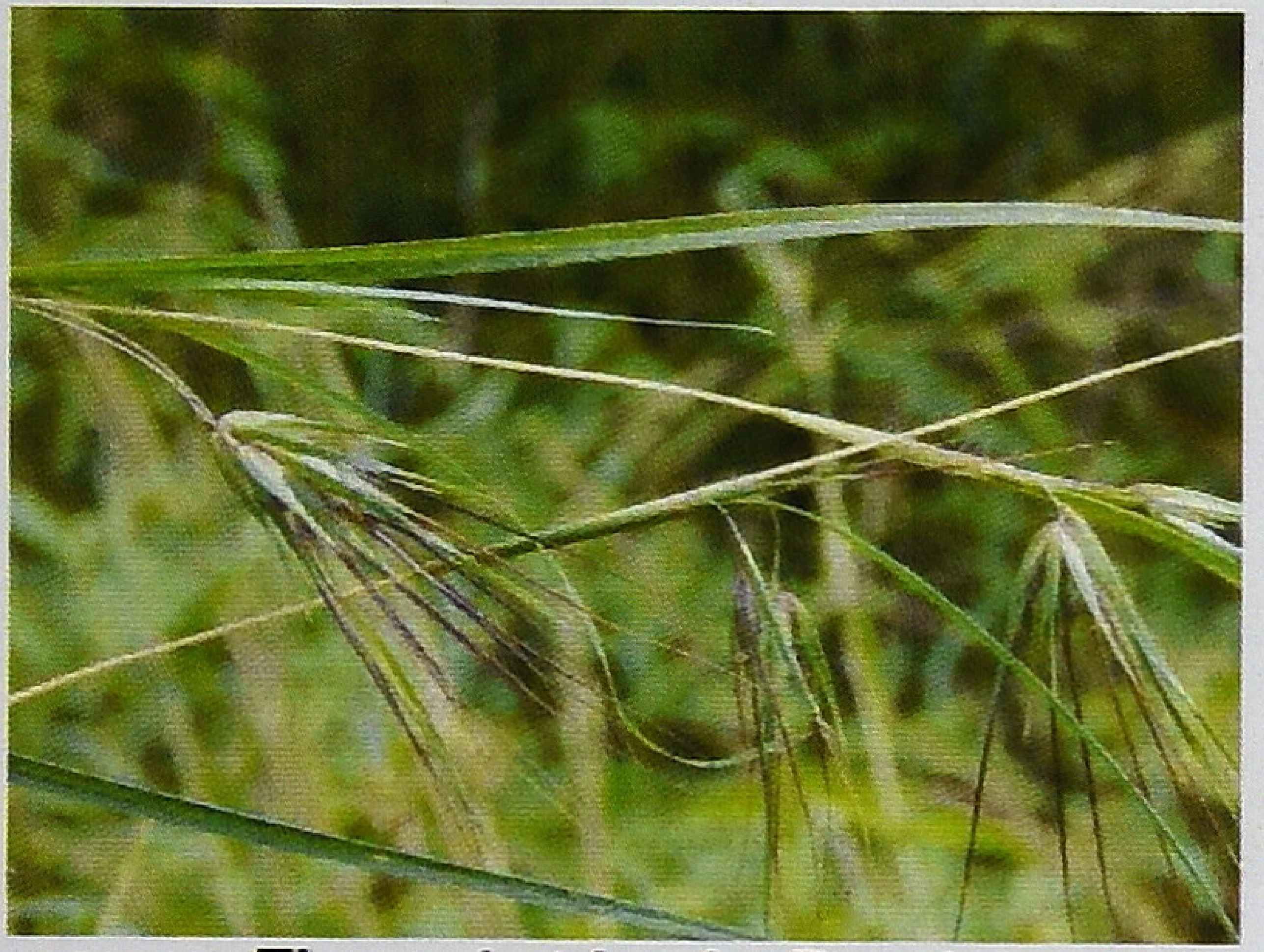
Ipomoea parasitica (Kunth) G. Don



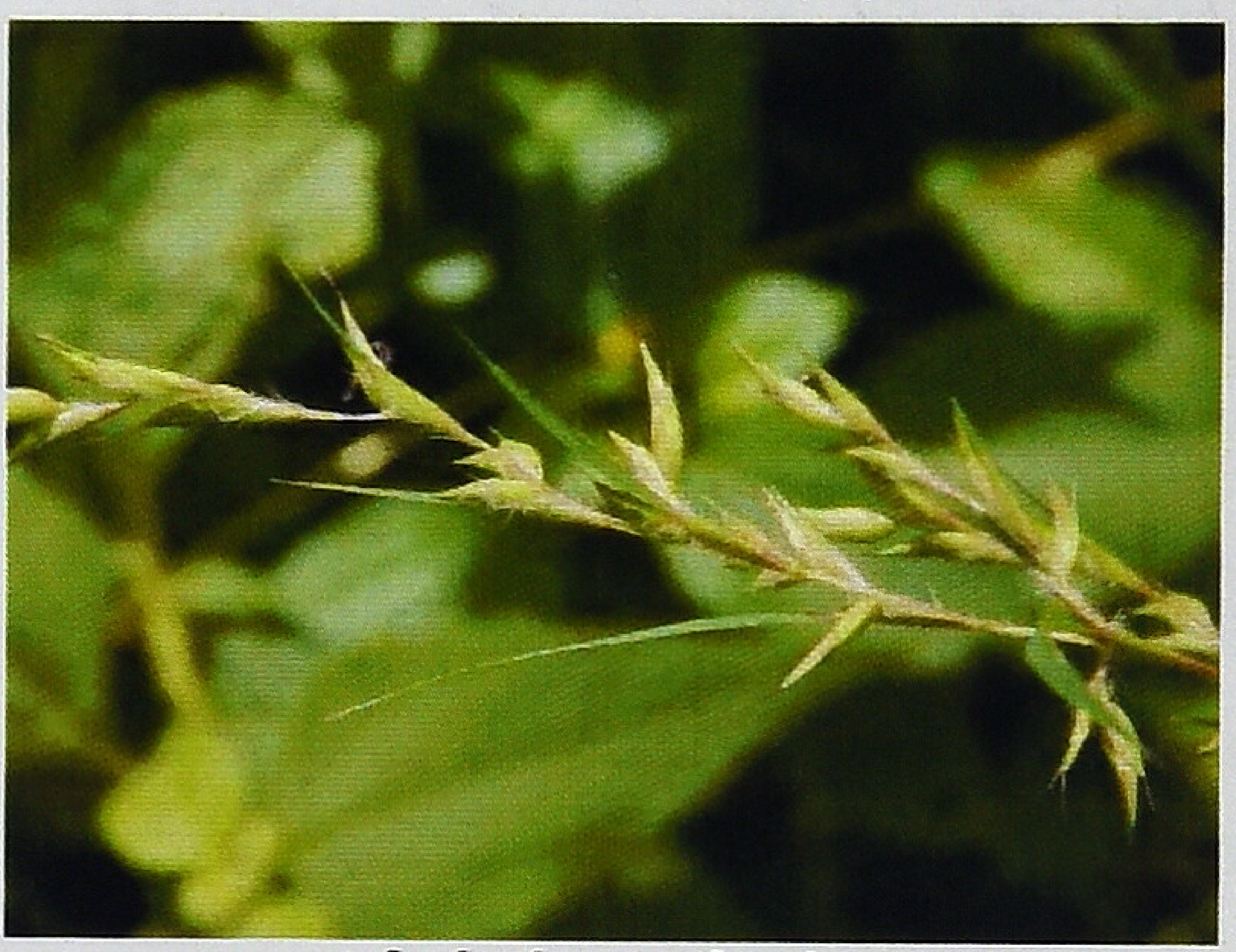
Mimosa pudica L.



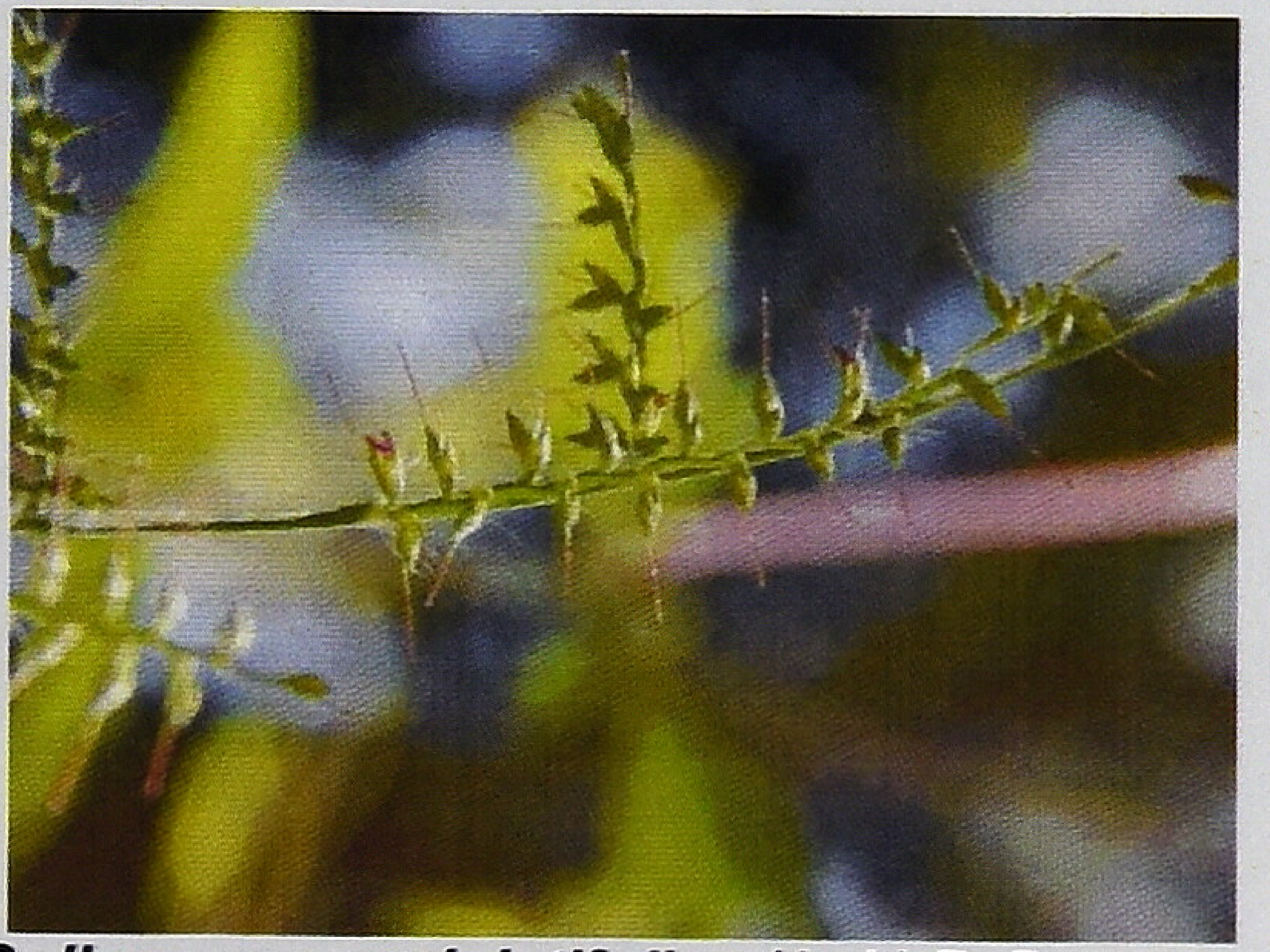
Senna occidentalis (L.) Link



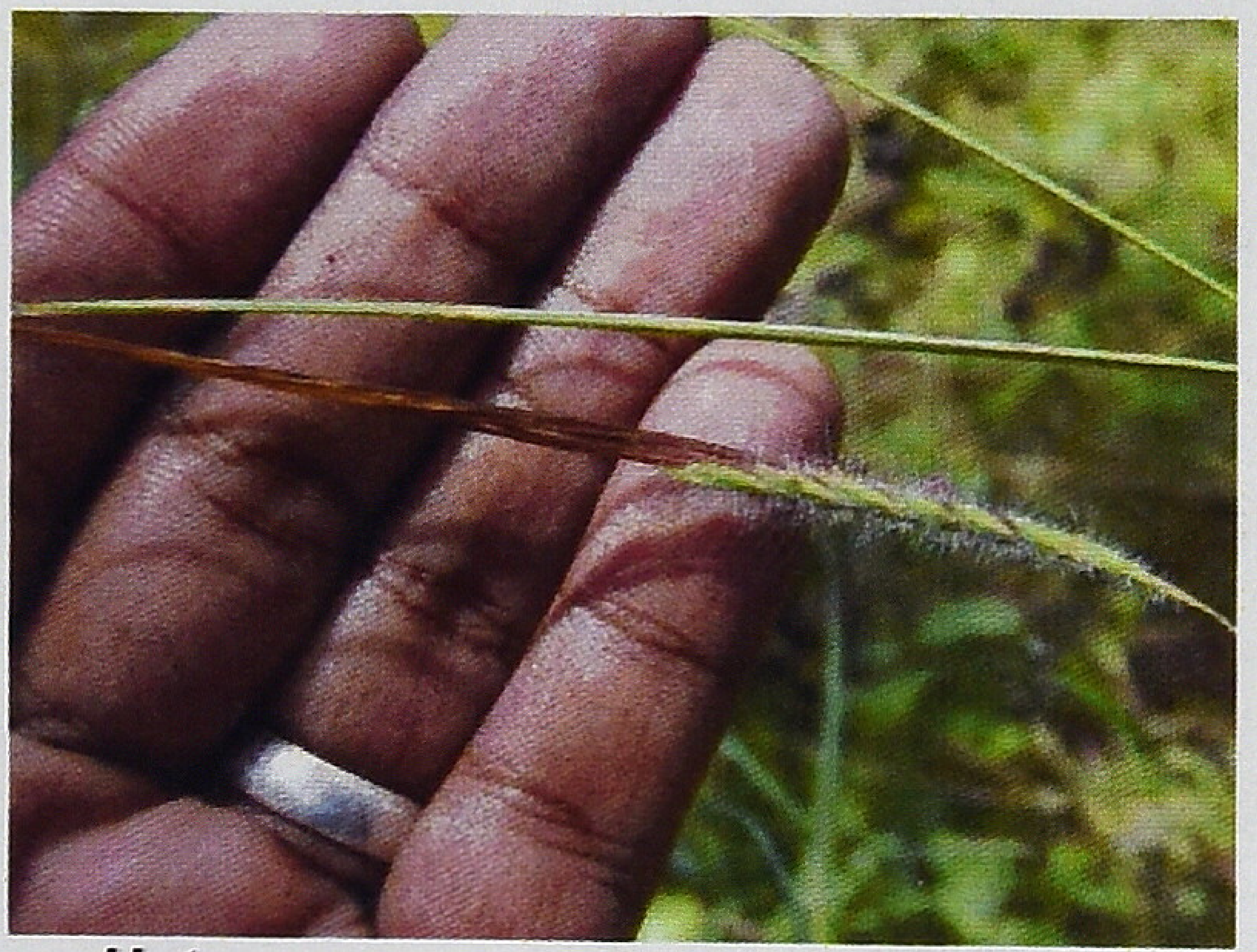
Themeda triandra Forssk.



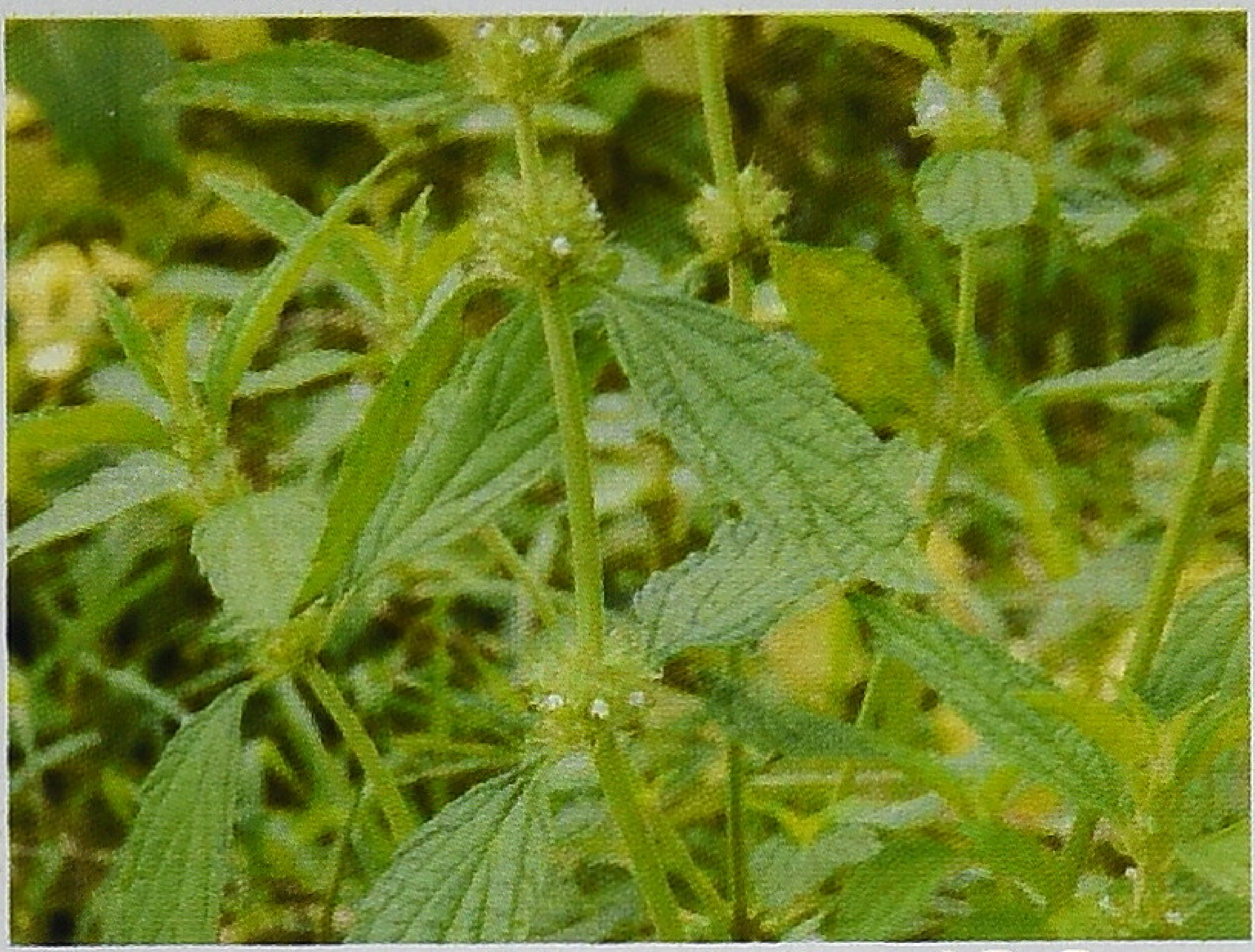
Apluda mutica L.



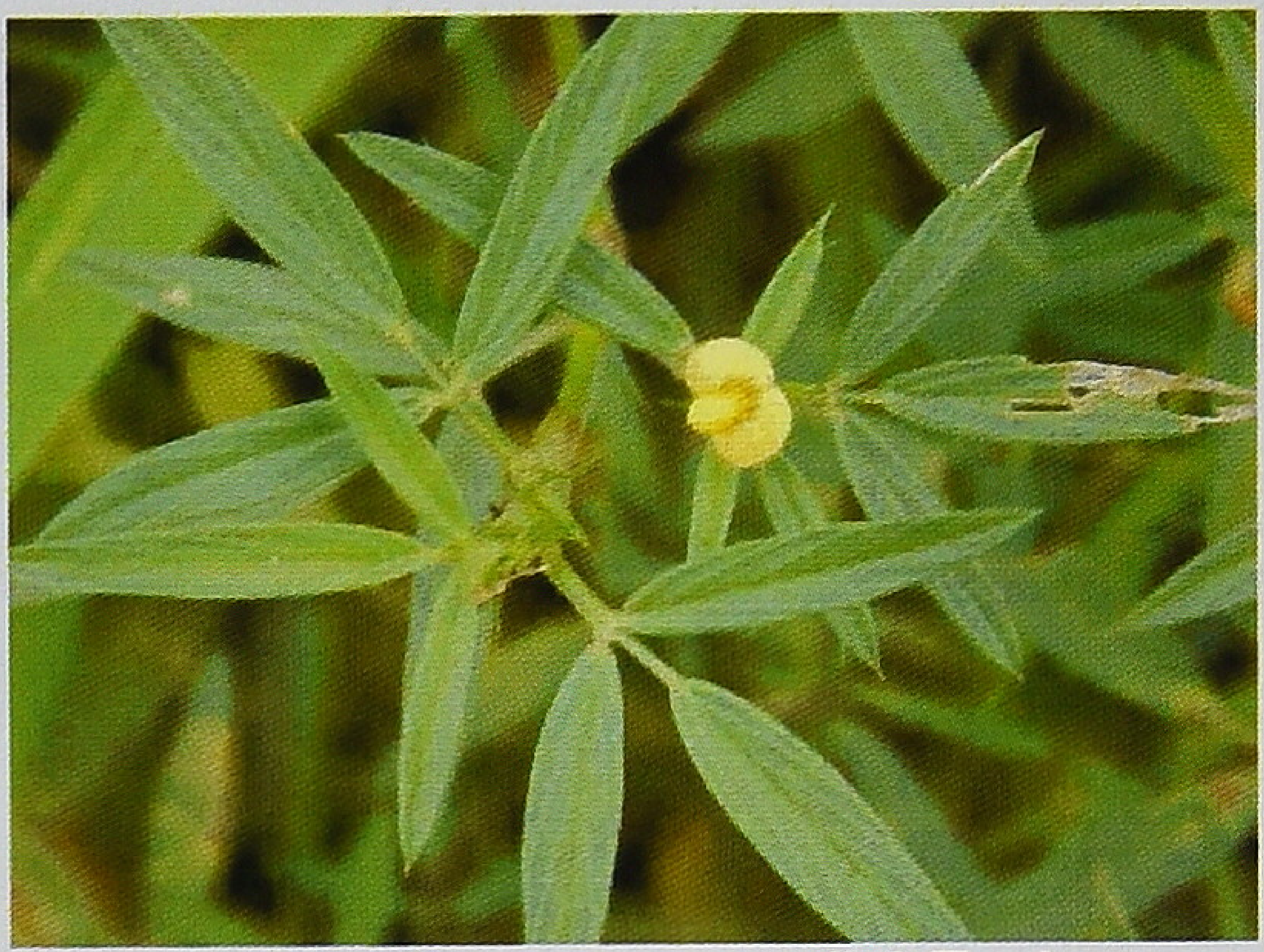
Oplismenus undulatifolius (Ard.) P. Beauv ex Roem. & Schultes



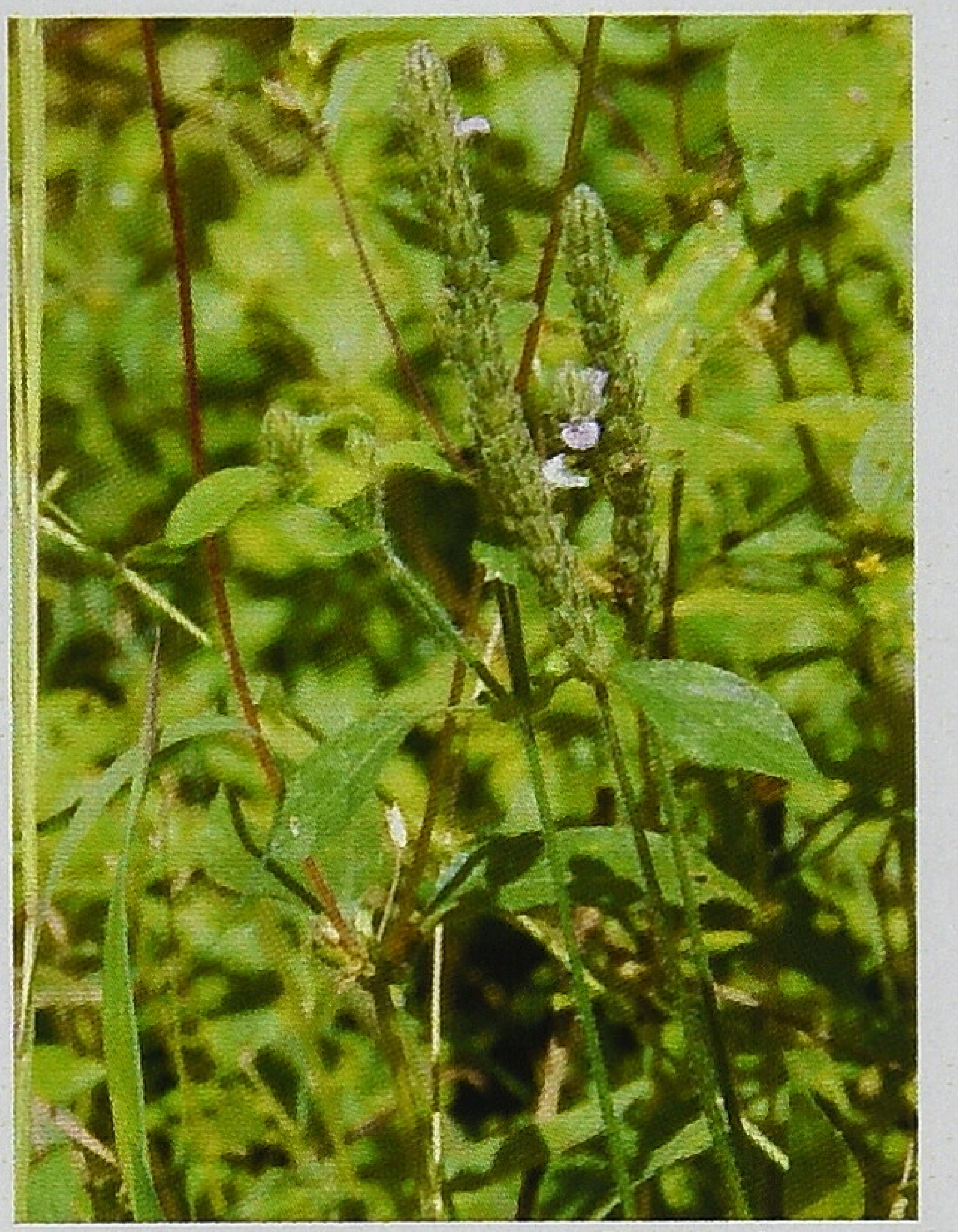
Heteropogon contortus (L.) P Beauv



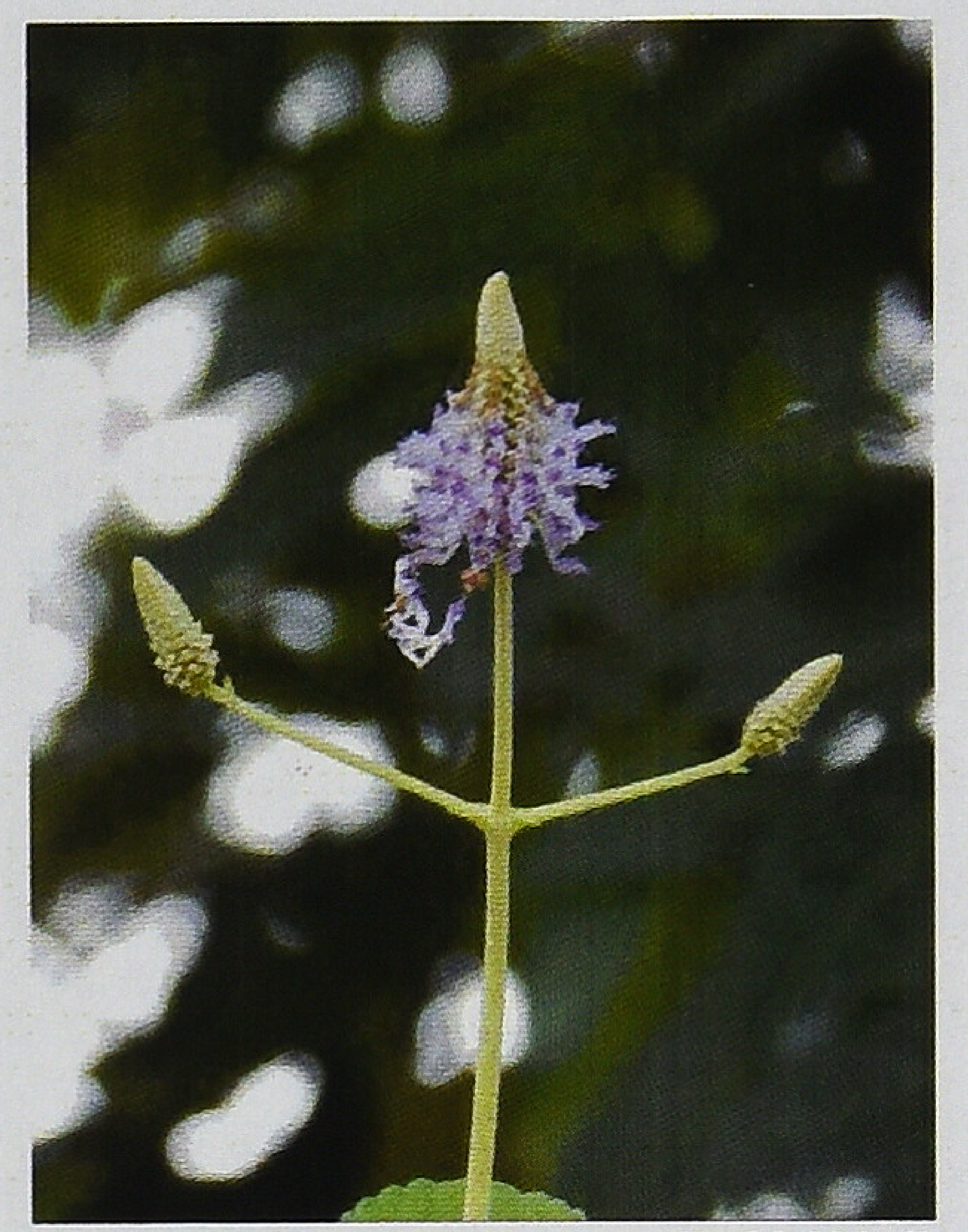
Leucas martinicensis (Jacq.) R. Br.



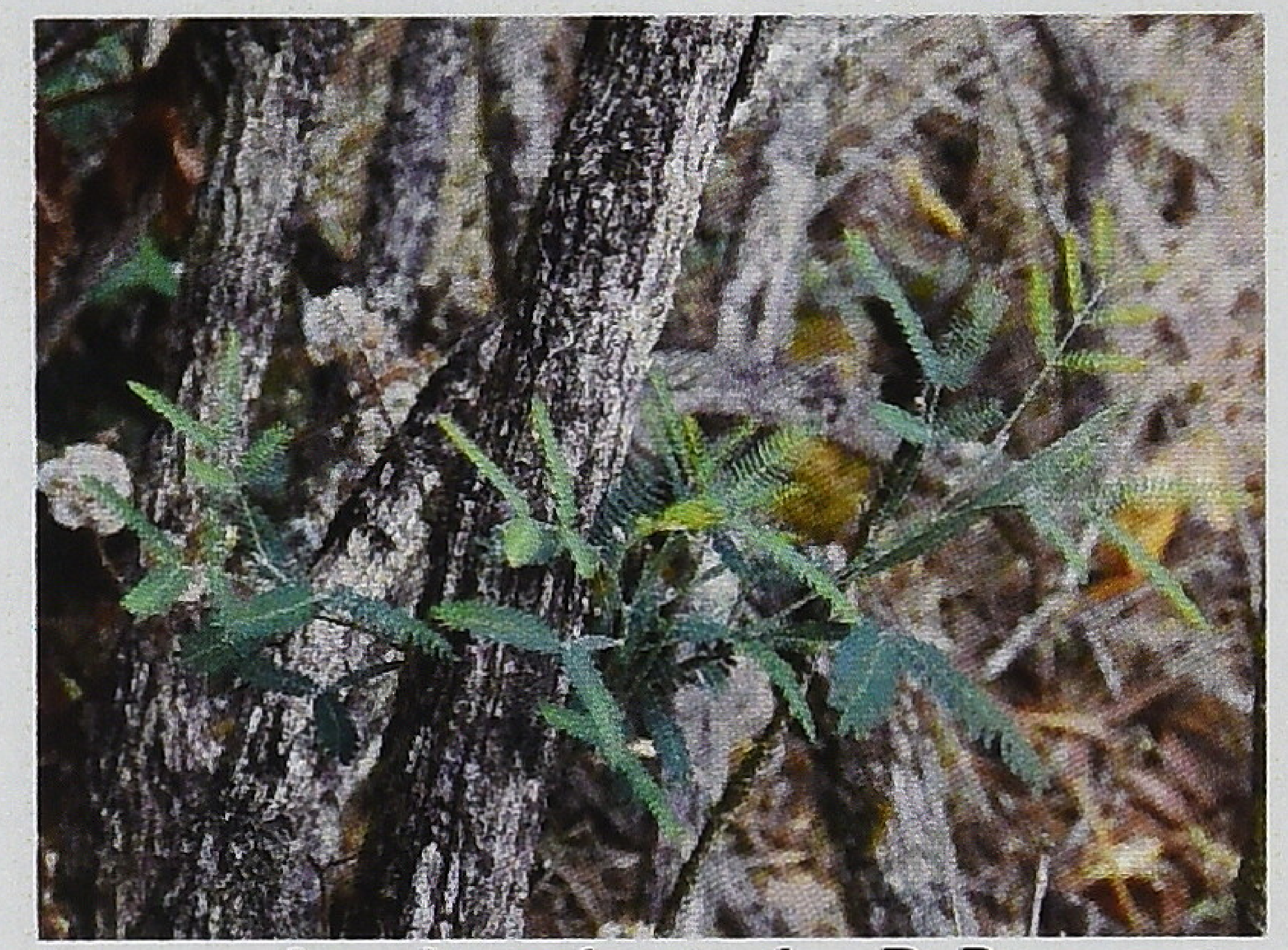
Stylosanthes hamata (L.) Taub.



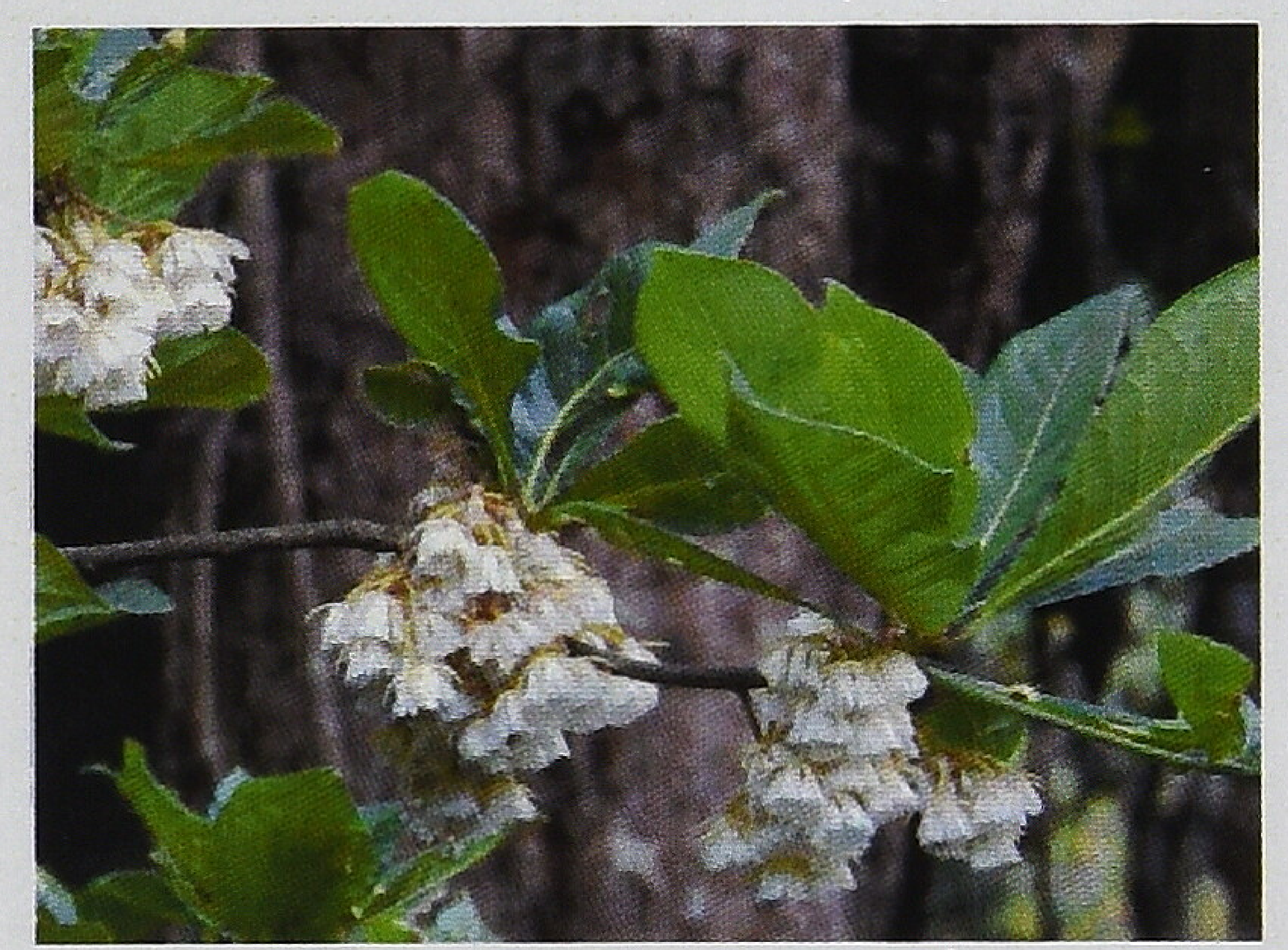
Justicia procumbens L.



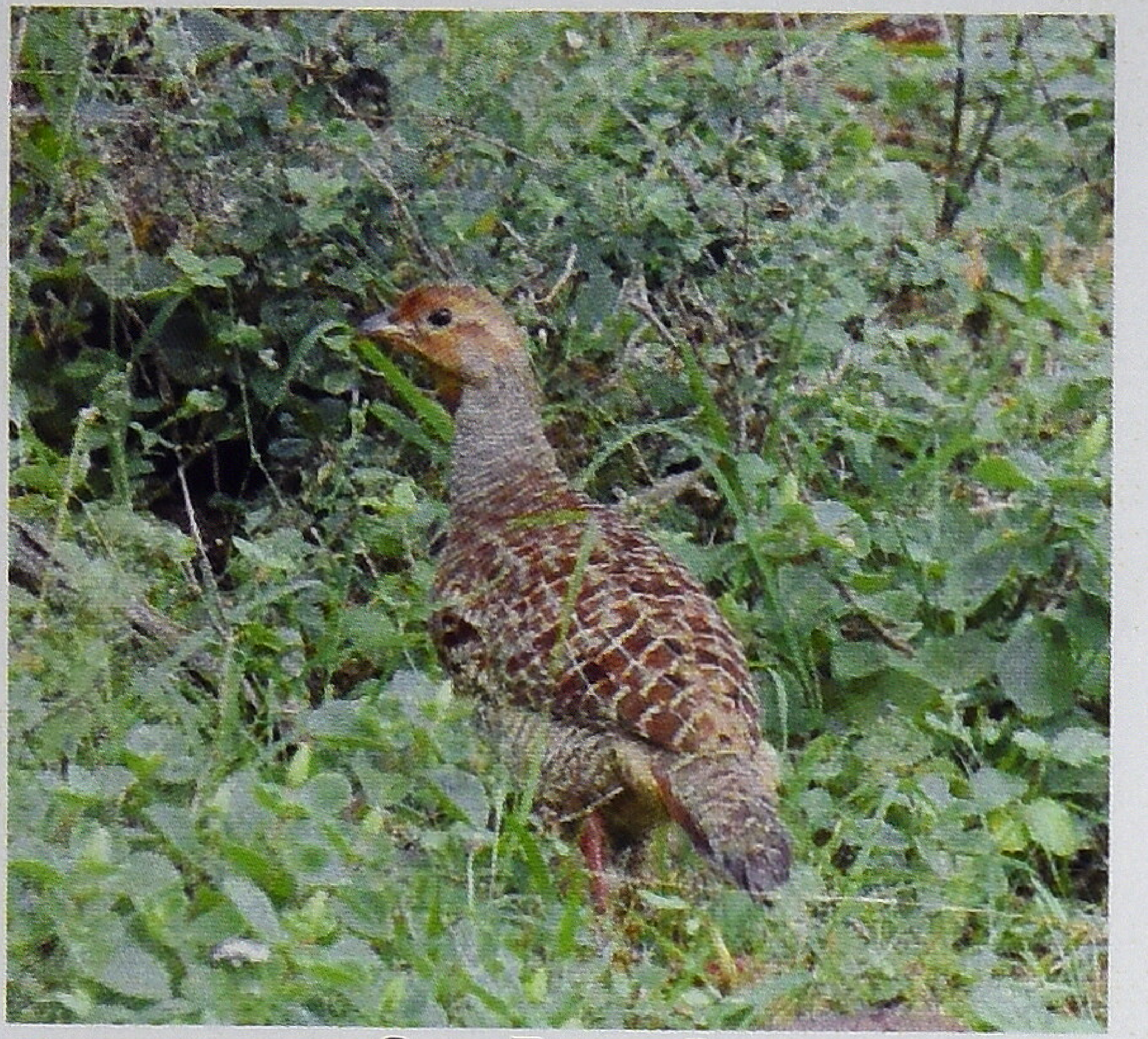
Anisochilus carnosus (L.f.) Wall.



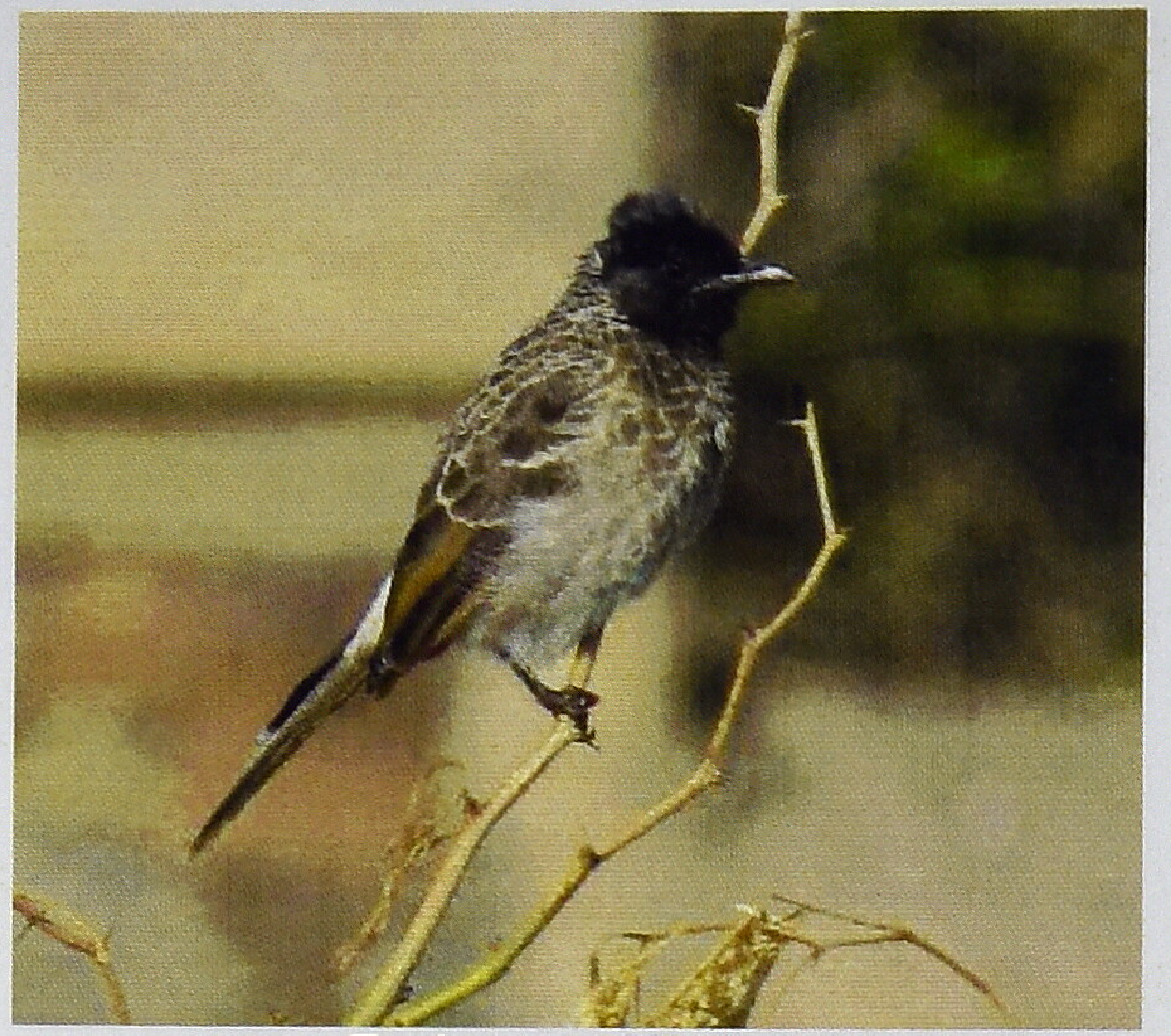
Acacia melanoxylon R. Br.



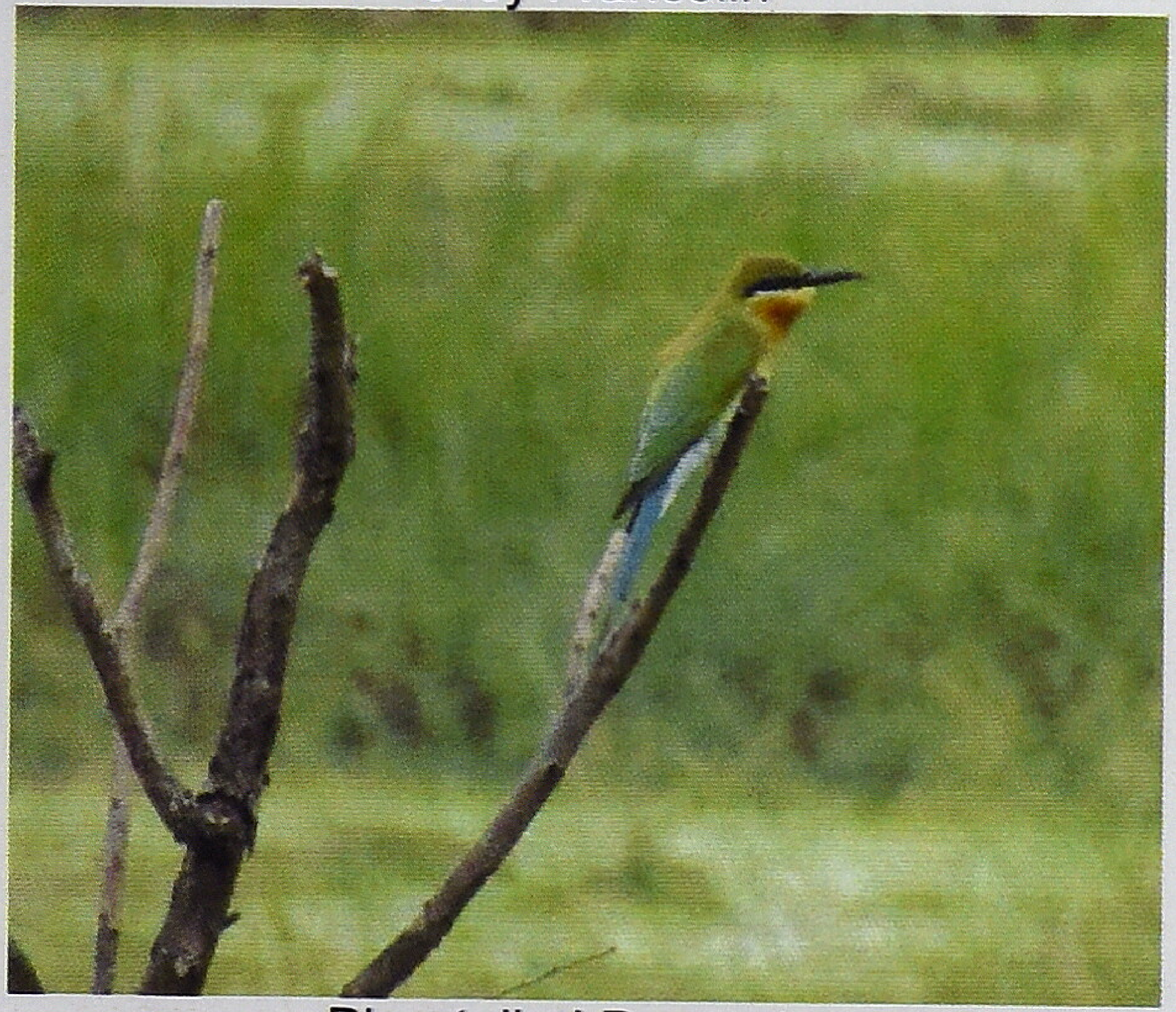
Elaeocarpus serratus L.



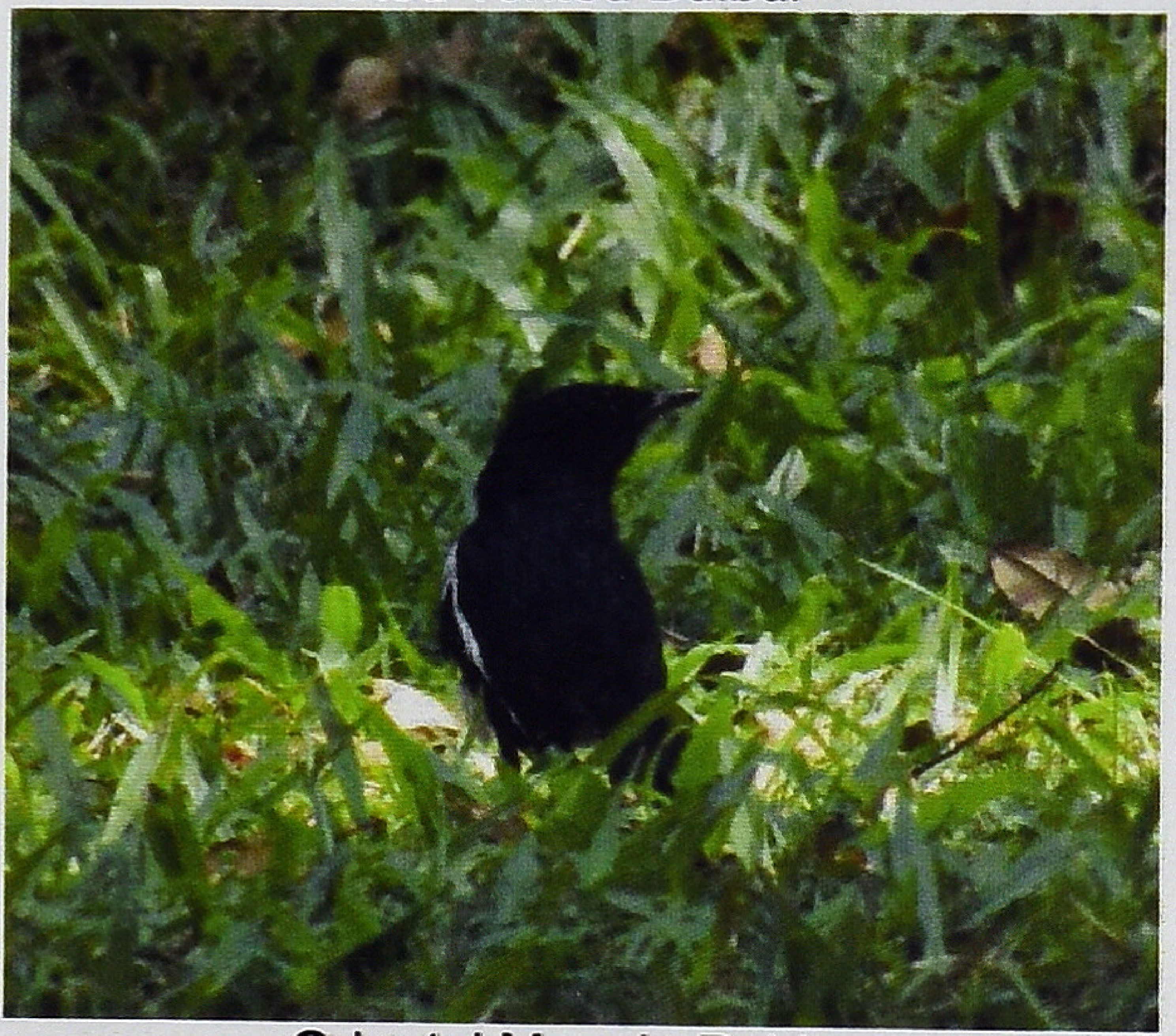
Grey Francolin



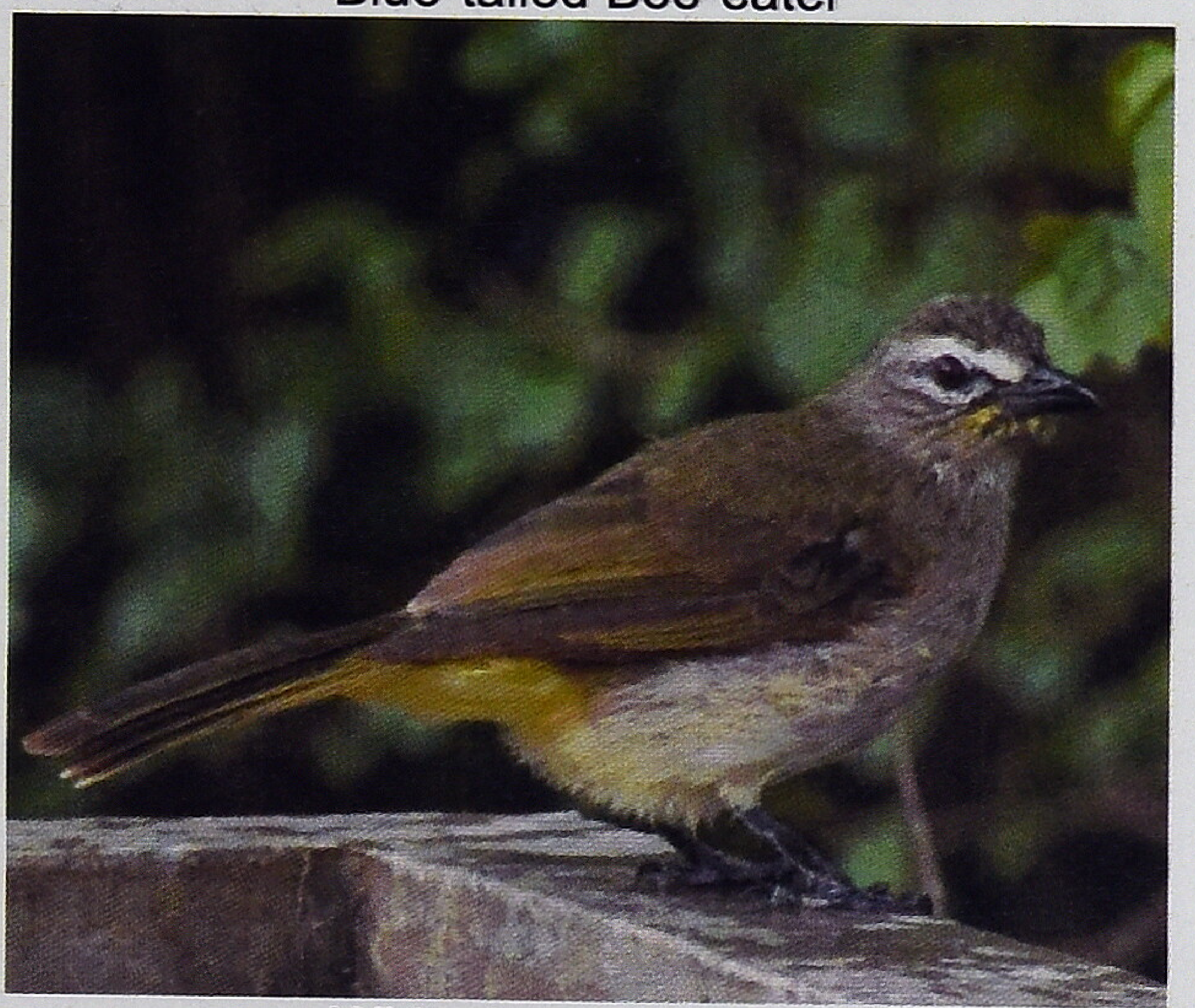
Red-vented Bulbul



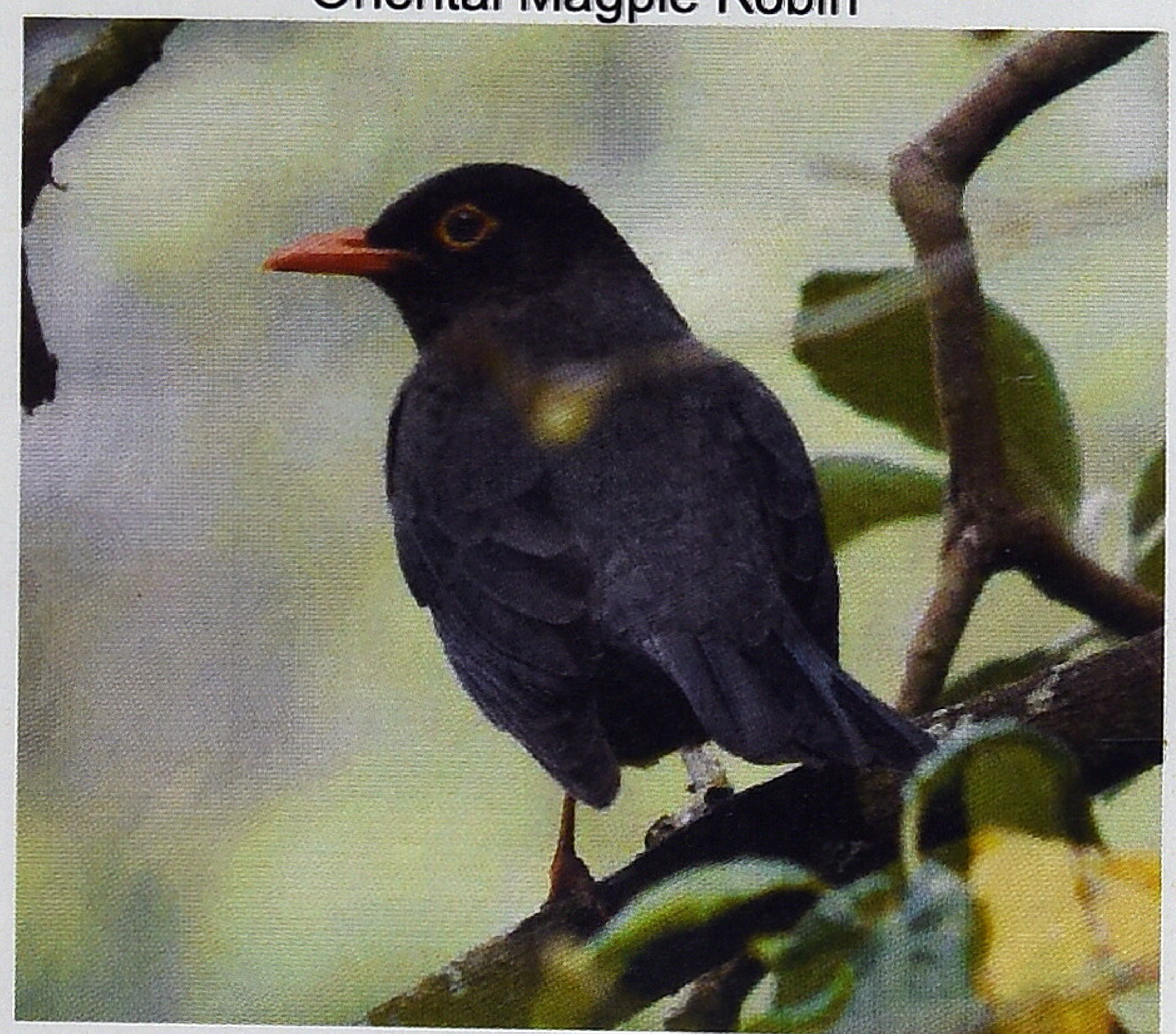
Blue-tailed Bee-eater



Oriental Magpie Robin

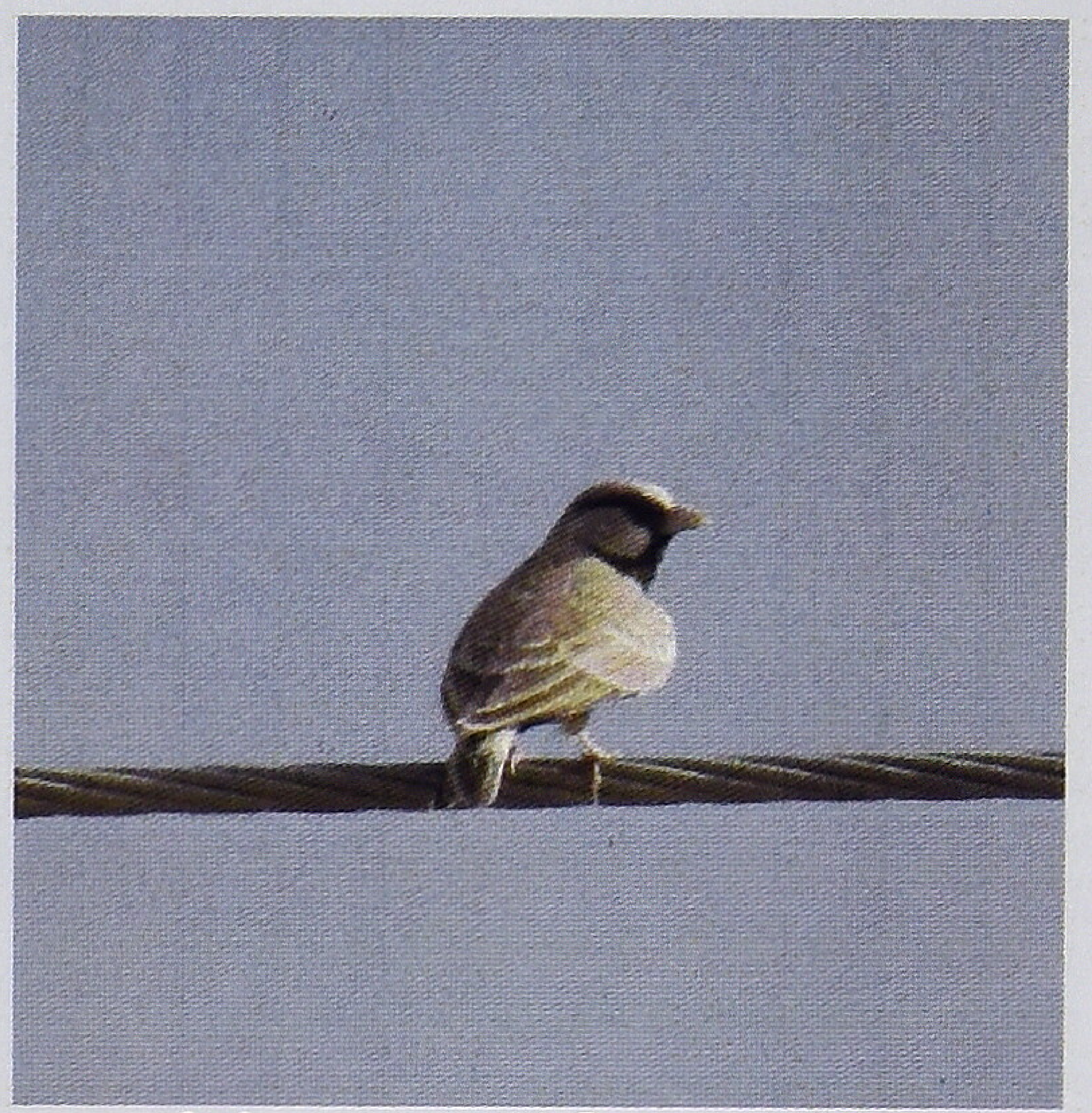


White-browed Bulbul



Indian Blackbird

Brahminy Kite

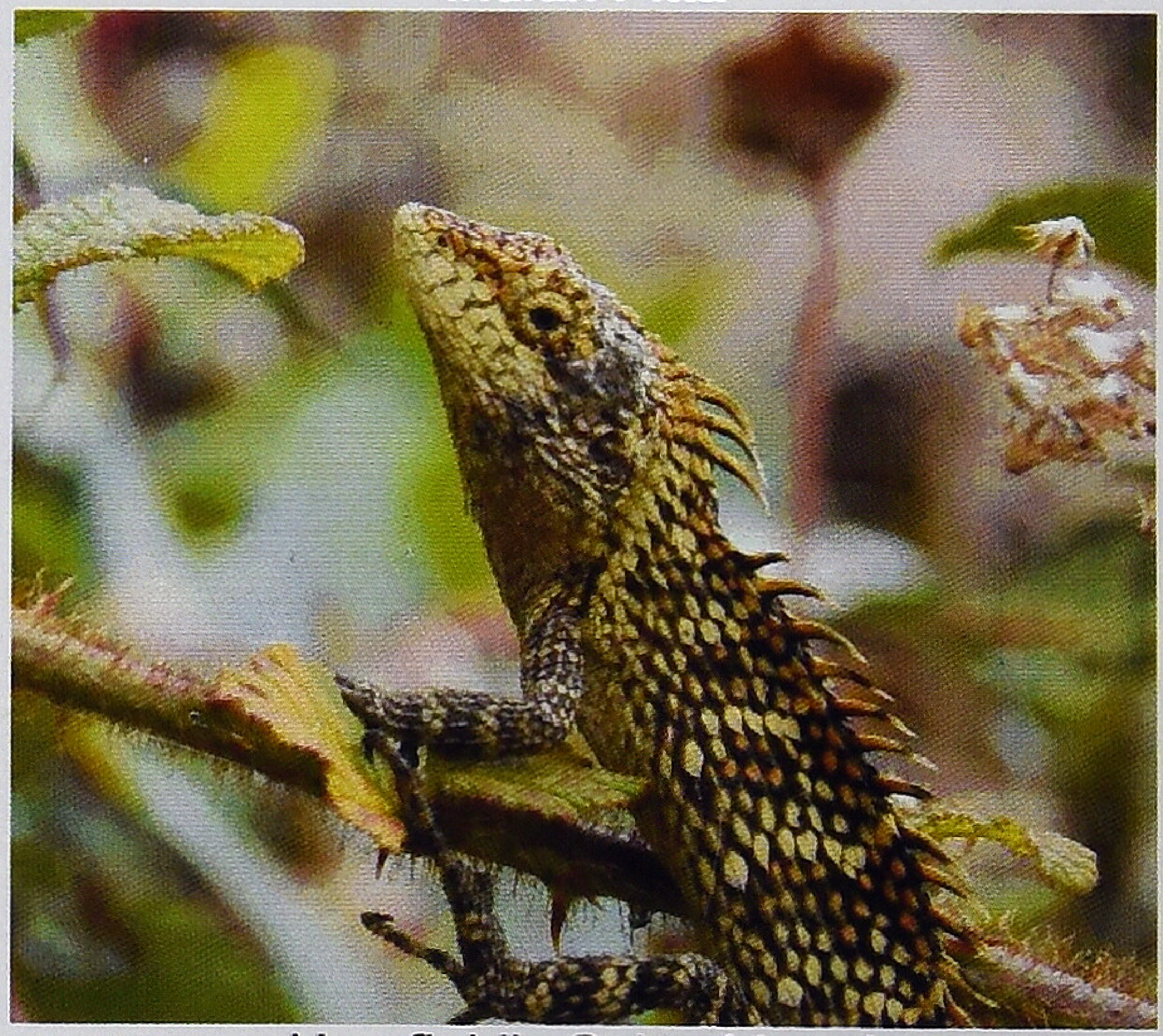


Ashy-crowned Sparrow-lark

Indian Robin

Indian Pitta

Blue Tiger



Horsfield's Spiny Lizard

Study carried out by

Care Earth Trust

Biodiversity. People. Conservation

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